JOURNAL

OF THE

AMERICAN SOCIETY OF NAVAL ENGINEERS

VOL. XVI. NOVEMBER, 1904. No. 4.

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U. S. BATTLESHIP *OHIO.*

DESCRIPTION OF VESSEL—OFFICIAL TRIAL PERFORMANCE.

BY LIEUT. J. F. BABCOCK, U. S. NAVY, MEMBER.

The *Ohio* is a twin-screw, armored battleship, built by the Union Iron Works, San Francisco, California. The contract was signed October 5, 1898, the keel laid April 22, 1899, and the hull launched May 18, 1901. The contract price was $2,899,000, of which $850,000 was for machinery. This price does not include the armor and armor bolts (exclusive of the requirements of the protective deck), the ordnance and ordnance outfit, and certain articles, as anchors and chains, supplied by the Government, but, does include the fitting and installing of the above.

The time allowed for completion was thirty-two months, but this was afterwards extended to thirty-eight months for: Difference between actual and nominal date of signing contract; delay due to change in plans and other causes; delay occasioned by change in arrangement of 6-inch gun ports; delay due to and consequent upon strike; delay in delivery of armor; changes in

turret and 6-inch gun foundations. In other words, the date of completion was extended from June 5, 1901, until September 10, 1904.

The collective indicated horsepower of propelling, air-pump and circulating-pump engines was to be 15,100 when the main engines were making about 120 revolutions per minute.

The speed guaranteed was an average of 18 knots an hour, maintained successfully for four consecutive hours, during which period the air pressure in the ash pits was not to exceed an average of two and one-half inches of water, the vessel to be weighted to a mean draught of 23 feet 6 inches. By the terms of the contract, a penalty at the rate of $25,000 per quarter knot was to be inflicted for speeds between 18 and 17½ knots, and a penalty at the rate of $50,000 per quarter knot for speeds between 17½ knots and 17 knots; and, further, if the vessel failed to exhibit an average speed of at least 17 knots an hour, it was optional with the Secretary of the Navy to reject her or to accept her at a reduced price.

The complement is 629 men and 42 officers.

HULL.

Length between perpendiculars, feet	388
on L.W.L., feet	388
over all, feet and inches	393–10¼
Beam, extreme, feet and inches	72– 2½
at L.W.L., feet and inches	72– 2½
Ratio of length (between perpendiculars) to beam	5.37
Depth (molded), feet and inches, main deck	34– 6
upper deck	42– 6
Height, flying bridge above main deck, feet and inches	33– 0⅝
Draught, normal, mean, feet and inches	23– 6
Displacement, light condition (20 feet 8 inches), tons	10,781
normal draught (23 feet 6 inches), tons	12,508
full-load draught (25 feet 10 inches), tons	13,941
per inch at L.W.L., tons	51.24
Area midship section to L.W.L., square feet	1,613.19
L.W.L. plane (23 feet 6 inches), square feet	21,521
Wetted surface (23 feet 6 inches), square feet	36,635
Center of gravity of L.W.L. plane, forward of M.S., feet	3.58
buoyancy above bottom of keel, feet	12.86
forward of M.S., feet	1.02

Center of gravity above bottom of keel, feet	
Transverse metacenter above center of buoyancy, feet	17.16
Longitudinal metacenter above center of buoyancy, feet	422.90
Coefficient of fineness, block	.6649
of M.S.	.9498
L.W.L.	.7681
Cylindrical coefficient	.6994
Number of frames (main)	98
watertight compartments	320

The hull is of basic open-hearth steel, of domestic manufacture. The frames stand square to the load line and are spaced 4 feet apart, except where intermediate frames are required, from stem to frame 81; from this point aft the frames are spaced 3½ feet apart.

There are 320 watertight compartments, of which 22 are in the double bottom. The double bottom proper extends from frame 29½ to frame 71. Forward and aft of these points, or throughout the limits of the magazines, the bottom plating of the magazines forms a continuation of the inner bottom; in the shaft alleys the plating continues to frame 83. A cofferdam, 36 inches wide, is constructed between the berth and protective decks on each side of the vessel, extending from the diagonal armor bulkheads to the ends of the vessel. Above the berth deck the cofferdam extends from frame 9 to frame 86.

The cofferdams are filled with fire-proofed corn-pith cellulose, made in suitable briquettes, and compressed to a density of from 8 to 9 pounds per cubic foot. All wood used in the construction, with the exception of the teak armor backing, is fire-proofed, and the use of wood is avoided as far as possible. The bridge deck, upper deck and the main deck outside of the superstructure are laid with wood, the others are covered with linoleum.

Two military masts are fitted, each one having two tops for machine guns and each fitted with a yard for signal purposes.

Bridge Deck.—The bridge deck forms the top of the superstructure and extends from turret to turret. Above this deck at each end are the upper bridges, and above the forward upper bridge is the flying bridge. Forward on this deck is the conning tower, on each side of which is an armored signal station for

directing the submerged torpedo discharge; aft is the armored signal tower. Four 3-pounder guns are mounted on each upper bridge and on the forward upper bridge are the captain's sea cabin and the navigator's office. The engine-room hatches end at this level, and the two boat cranes are mounted on this deck. The boats and the 1-pounder and 3-inch guns are carried on this bridge deck.

Upper Deck.—The upper deck extends from the after turret to the stem. The superstructure is carried on this deck, extending forward to the foremast. Forward of the foremast the upper deck forms the forecastle, above which is the forward 12-inch turret. Four 6-inch guns, protected by armor, are carried inside the superstructure. The fire-room hatches end above this deck. Inside the superstructure are the crew's galley, the officers' galley, the bakery, the junior officers' mess room and pantry, two junior officers' state rooms, the junior officers' bath room, the chief of staff's state room, bath and office, three ward room officers' state rooms, the executive's office and the ordnance officer's office. Forward, inside the superstructure, are two winches, and forward of the turret is the windlass enclosure. Four davits on either side of the forward part of the superstructure give harbor hoisting places for four boats.

Main Deck.—The main deck extends from stem to stern and carries the casemate. Aft of the casemate this deck forms the quarter deck, above which is the after 12-inch turret. Abaft the turret is a steam winch and a capstan. On either side of the quarter deck are two davits for hoisting the barge and gig in harbor. Inside the casemate are ten 6-inch rapid-fire guns, five in broadside, separated from each other by splinter bulkheads. Inside the casemate are the warrant officers' quarters, the officers' water closets, armories, and inside the fireroom hatches the drying rooms. Well forward of the casemate on this deck, one on either side, are two 6-inch guns protected by armor. Forward of these guns, in the eyes of the ship, are the crew's water closets, wash places and showers. The paymaster's office is forward on this deck. The greater part of the crew berth on this deck in hammocks.

Berth and Protective Deck.—The berth deck extends from stem to stern and between the turrets, or, in other words, inside the diagonal armor it is the protective deck. Forward and aft of the diagonals of armor the protective deck slopes down away from the berth deck, and the space thus formed is made into storerooms. Aft on the port side are the Admiral's quarters and on the starboard side are the Captain's quarters; forward of these quarters are the wardroom, officers' quarters, the mess room amidships and the rooms outboard. Just forward of the after diagonal armor on the starboard side are the wardroom pantry and three staterooms with a coal bunker outboard, and on the port side are two wardroom bathrooms and three staterooms with a coal bunker outboard. Passages run fore-and-aft on each side of the midship line on this deck in the section enclosed by armor. Between the passageways are the machine shop, the engine-room hatch, the distiller room, the uptakes, the firemen's wash rooms and the petty officers' wash rooms. Outboard of the passageways are coal bunkers and forward on the port side the machinists' quarters, on the starboard side the petty officers' quarters. Forward of the diagonal armor is a compartment containing on the port side the brigs, amidships the coal storage rooms, and on the starboard side the ice-machine room, the band room, Master-at-Arms room and the printing office. Forward on this deck are the dispensary, the operating room, the sick bay and the sick-bay bathroom. Forward of the diagonal armor this deck furnishes berthing space (hammocks) for a part of the crew.

Splinter and Platform Decks and Hold.—There are, below the protective deck, the engine rooms, dynamo rooms, firerooms, blower rooms, storerooms, magazines, shell rooms, handling rooms, ammunition passageways, coal bunkers, submerged-torpedo room, trimming tank, fresh-water tanks and ammunition hoists.

Drainage System.—The main drain pipe is of 15-inch galvanized steel tubing. It runs above the inner bottom on the starboard side from just forward of the forward engine-room bulkhead to the after part of the forward fireroom. It is connected by 15-

inch galvanized steel tubing to the main circulating pump in each engine room. In each engine and fireroom this drain has a branch suction pipe which extends down close to the inner bottom. In these branches are 14-inch stop check valves operated in their own compartments and also from the berth deck. Each one of the suction branches of the main drain connects by means of a 5-inch pipe with the principal pumps other than those used for feed and water service.

The secondary drain is of 5-inch galvanized steel tubing. It runs above the inner bottom on the port side from the after part of the port engine room to the forward bulkhead of the forward fireroom. It is connected by 5-inch tubing to all the principal steam pumps other than those used for feed and water service. This drain connects with manifolds in the after part of each engine room, in the port after fireroom and in the forward part of each forward fireroom. The engine-room manifolds connect by means of 4-inch galvanized suction pipes to the compartments aft of the after engine-room bulkhead. These suction pipes run under the inner bottom. The forward manifolds connect by means of the same sized suction pipes to the compartments forward of the forward fireroom bulkhead, the suction pipes running under the inner bottom. The manifold in the port after fireroom connects by means of 4-inch galvanized pipes, running above the inner bottom, with the double bottom compartments in the boiler spaces. Each engine room and fireroom compartment is fitted to be drained by 4-inch suction pipes leading to the pumps in the respective compartments. In the engine and boiler compartments branch suctions from the secondary drain run into wells fitted with plate strainers and extending a little below the inner bottom. The compartments above the protective deck are drained by scuppers or portable pumps.

Ventilation.—Electrically driven blowers accomplish the ventilation of the ship. All supply blowers take fresh air from ventilators which extend above the awnings. Each dynamo room has one number 50 supply blower. Each engine room has one number 80 supply blower. For the crew's water closets one

number 2 exhaust blower is fitted on each side and one number 1 exhaust blower is connected to the two officers' closets.

One number 70 blower on the berth deck at frame 18 supplies all the storerooms and living quarters forward of that bulkhead. In the forward blower room, which is on the splinter deck aft of the forward turret, are two number 45 blowers, which supply magazines and storerooms forward of dynamo rooms and aft of the turret.

Foul air ducts lead up from the starboard and port upper dynamo rooms and each is fitted with a number 5 induction blower. Two number 5 blowers are in the conning tower support on the berth deck, and supply berth deck passages and petty officers' quarters and have ventilating branches leading to the ammunition passageways. In the ammunition passageways, near the auxiliary magazines on either side, a number 0 blower causes circulation through air lagging of auxiliary magazines, air being taken from the passageway and discharged into the same.

In the distiller room on either side are two number 4 blowers, which supply the distiller room, the warrant officers' quarters and the berth-deck passageways.

In the machine shop on the starboard side is a number 5 blower, which supplies the machine shop and the quarters on the berth deck inside the diagonal armor and has a ventilating branch to the ammunition passageway. A number 5 blower having the same connections is placed on the port side in the passage abaft the machine shop.

In the after blower room on the splinter deck, at frame 73, are two number 45 blowers, which supply the magazines and store rooms aft.

In the steering-engine room are two blowers. The starboard one is a number 45, and supplies storerooms and passageways from frame 80 aft. The port one is a number 50, and supplies the officers' quarters.

ARMOR.

The armor is arranged in the same manner as on the *Maine* and the *Missouri*. The belt armor has a maximum thickness of 11 inches from the top down a distance of 4 feet 6 inches and then

slopes to 7½ inches at the bottom. The thickness of this belt is decreased forward of frame 27. The four forward plates are 4 inches thick top and bottom. The diagonal armor is 9 inches thick. The casemate armor above belt is 6 inches thick. The superstructure armor is 6 inches thick as is also the armor forward and the casemate on the upper deck amidships. Diagonal armor above belt is 6 inches thick.

The conning tower is 10 inches thick with a 2-inch top and the signal station aft is 6 inches thick. The turrets are 11 inches thick with 12-inch front plates and 3-inch tops. The barbettes are 12 inches thick for two-thirds of the circumference and 8 inches thick at the part next the superstructure.

ORDNANCE.

Main Battery.

Four 12-inch breech-loading rifles, Mark III, in two balanced turrets, electrically operated.

Sixteen 6-inch rapid-fire guns, Mark VI, 50 calibers.

Secondary Battery.

Six 3-inch rapid-fire guns, Mark III.

Eight 3-pdr. rapid-fire guns, Mark IV.

Two 1-pdr. rapid-fire guns.

Four 1-pdr. automatic guns.

Two Colt automatic guns.

Two 3-inch field pieces.

Torpedoes.

Two submerged torpedo tubes.

AMMUNITION SUPPLY.

12-Inch Guns.—The ammunition for the 12-inch guns is stowed forward in two shell rooms and eight magazines, and aft in three shell rooms and seven magazines, all of which open into the handling rooms, which are situated directly under the turrets. The shell is lifted in a horizontal position by a differential purchase and shell tongs, and is run on trolleys into the handling room and placed on a car, which runs on a circular track on handling-room floor. The ammunition-hoist rails run down into the handling room, revolve with the turret, and the handling-room

car may be locked to these rails and made to revolve with them, thus facilitating the putting of the shell into the hoist. The shell is shoved by hand into the shell section of the ammunition car. Powder is passed by hand through scuttles in magazine doors and put into the powder sections of car. The loaded car, one for each gun, is hoisted by an electric motor operated from the turret to a point directly in rear of the gun.

6-*Inch Guns.*—Forward on the hold deck there are two 6-inch magazines, one on either side of the midship fore-and-aft line. Outboard of these magazines and opening into them are three compartments on each side. These compartments are shellrooms with the exception of the center one on the port side which is a magazine. Forward in each forward outboard shellroom, and aft in each after outboard shellroom and midship magazine, is a combined shell and powder, vertical, electrically operated chain hoist. The two forward hoists run to the main deck forward of the diagonal armor on each side to a point about 25 feet abaft the two forward 6-inch guns and supply ammunition to them. The four after hoists run to the main deck inside the diagonal armor, two on either side, to points a little forward and inboard of the two forward 6-inch casemate guns and supply ammunition to the four forward 6-inch casemate guns. The ammunition is transported from hoists to gun by hand.

Aft on the hold deck, on either side of the midship fore-and-aft line, are two 6-inch magazines with a manhole in the fore-and-aft bulkhead between the two. An inclined electrical powder hoist is placed on the forward bulkhead of each of these magazines. On the splinter deck, between frames 77 and 80, are four 6-inch shellrooms placed in an athwartship line. The two inboard of these shellrooms are used for the after casemate guns, the shell being run on trolleys from the shellrooms over a platform running above the after 12-inch handling room, through the blower rooms to inclined electrical chain hoists, between frames 70 and 71. These four after hoists run to the main deck between frames 68 and 69, two on either side, and supply the four after 6-inch casemate guns.

On the splinter deck, between frames 43 and 51, outboard of

the ammunition passages, on each side are two auxiliary magazines. Between frames 43 and 59 in these passageways on either side are three 6-inch vertical, electrical, combined shell and powder hoists. The forward hoists go to the main deck inboard and just forward of the midship 6-inch casemate guns on either side. The two after hoists run to the upper deck, two on either side, almost directly in rear of the upper deck 6-inch guns. When there is ammunition in these auxiliary magazines ammunition is transported from them to these three hoists on either side. If there is no ammunition in these auxiliary magazines shell will be transported from the after 6-inch outboard shell rooms to these hoists, and powder will be brought from the forward magazines, being whipped by hand, to the splinter-deck level through a hatch between frames 29 and 30.

The powder goes to guns in tanks and the shell goes up in slings.

3-Inch Rapid Fire.—Forward on the port side of the splinter deck, between frames 20 and 27, is a 3-inch R. F. fixed ammunition room. The ammunition is transported from this room aft on the port side to a hoist in the ammunition passage about frame 36. Aft on the starboard side, between frames 74 and 77, is a 3-inch R. F. fixed ammunition room. The ammunition is transported from here forward to a hoist in the passage at frame 65. These hoists are electrically operated, vertical, and run to the upper deck. On the upper deck are five electrical whip hoists: one forward on the port side; two amidships, one on either side and one aft on either side. Ammunition is transported from the two shell room hoists by hand to the whip hoists and whipped up to the bridge deck, in rear of the 3-inch R. F. guns.

3-Pounder, 1-Pounder, Colt Automatic and 3-Inch Field Guns.—The fixed ammunition for these guns is stored in fixed ammunition rooms on the splinter deck, forward on the starboard side and aft on the port side, directly across the ship from the 3-inch R. F. ammunition rooms. The hoists for this ammunition are similarly placed to the 3-inch hoists, on the opposite side of the ship. These hoists are vertical, electrically operated and run to the upper deck. The 3-pounder ammunition after reaching the

upper deck is transported by hand to four electric whip hoists, two forward and two aft, and by them whipped up to the bridges, each whip supplying two guns. The 1-pounder automatic and Colt automatic ammunition is taken from the ammunition room hoists to electric cage hoists and whipped to the lower tops. From the lower tops the Colt ammunition is whipped by electric whip hoists to the upper tops. The 1-pounder single ammunition is taken from shell-room hoists by hand and whipped up to the 1-pounder guns. The forward hoist for fighting-top guns is amidships near the foremast, and the after hoist is in the mainmast.

MAIN ENGINES.

There are two 4-cylinder, triple-expansion engines of the vertical, inverted, direct-acting type, placed abreast of each other in separate watertight compartments. The high-pressure cylinder is forward, next aft is the intermediate-pressure, followed by the two low-pressure cylinders. Each cylinder is supported on its outboard side by two forged nickel-steel, cylindrical columns, and on its inboard side by a heavy built-up, inverted Y, forged-steel framing, which carries the crosshead guide and supports the rocker shaft. Two forged, nickel-steel, cylindrical braces run from the inboard side of the bottom of the cylinders diagonally outboard, their lower ends securing to the framing outboard of the base of the vertical columns. Forged, nickel-steel rods, passing through brackets on the cylinders, secure the cylinders to each other in a fore-and-aft direction. On each side of these cylinder brackets, a nut working in a thread on the rod is placed, and by this means a fore-and-aft tension on each cylinder is obtained. These rods are fitted near the top and bottom of the cylinders, inboard and outboard.

Each cylinder has one valve. The high-pressure valve is of the single-ported piston type. It is made of cast iron and has no packing ring. The upper head of each valve is increased in diameter an amount sufficient to balance the weight of the valve. The intermediate and low-pressure valves are double ported slide valves. They are made of cast iron and are fitted with balance rings on back and with balance pistons.

The valve gear is of the Stephenson type, with double bar links. All the valve stems take hold of the link block directly Independent adjustable cut-off blocks are fitted to each link with a range of from about .5 to .7 of the stroke for the high pressure and intermediate pressure and from about .4 to about .6 of the stroke for the two low pressures.

Each engine has a throttle valve, with a clear opening of 13 inches diameter, made of composition, and bolted to the nozzle of the high-pressure valve chest. The valve is fitted with a toggle joint and screw provided with suitable gear for operating same from the working platform, an index to show the opening of the valve in tenths, and an auxiliary throttle or by-pass valve for use in running at low speeds. Pass-over valves are fitted to admit live steam to the intermediate and low-pressure receivers. The high-pressure cylinders are steam jacketed around the working liners, and the intermediate-pressure and low-pressure cylinders are steam jacketed around the working liners at both ends. The space left around the working linings for steam jackets is $\frac{3}{4}$ inch in depth.

The pistons are made of cast steel and are conical in shape. Each piston is fitted with a follower and two packing rings, each $1\frac{1}{4}$ inches wide and $\frac{3}{4}$ inch thick. The packing rings are made of hard cast iron cut obliquely, tongued and set out by steel springs. The piston rods are hollow and are made of forged nickel-steel, oil tempered and annealed. The pistons and crossheads are bolted to the piston rods, which are turned to fit the conical holes in each. The crossheads are made of forged steel, the pins are $9\frac{3}{4}$ inches in diameter by $9\frac{1}{4}$ inches long. Each crosshead has a wearing slipper of manganese-bronze, T section in form, faced on the sliding surface with white metal fitted in dovetailed recesses and hammered in place. The crosshead guides, of the slipper type, are made of cast iron and are hollow for the circulation of cooling water. They are bolted to the inboard cylinder support. The backing guides, of cast iron, are bolted to flanges on the go-ahead guides. The connecting rods, with their bolts and caps, are made of forged nickel-steel, oil tempered and annealed. The crosshead end of each rod is forked

to span the crosshead and is provided with caps and brasses. The crank-pin end of each rod is faced on each side and squared on the end for the brasses. This end is provided with brasses and steel cap.

The eccentrics are in two parts, the back or smaller part is of forged steel and the front part of cast iron. They are turned accurately on the outside to an eccentricity of 5½ inches. Each eccentric has adjustable side keys and is securely keyed to the shaft. The eccentrics have 5 inches face for ahead and 4 inches for backing, including the rabbet for the flanges of the eccentric straps. The eccentric straps are of composition lined with white metal. The two parts of each strap are held together by two forged steel bolts. The eccentric rods are of forged steel. Each rod has a T head secured to the eccentric strap. The upper end is forked to span the link. The distance from centers of eccentrics to centers of link pins is 7 feet 11½ inches.

The reversing gear for each engine consists of a steam cylinder and a hydraulic controlling cylinder, acting directly on two arms fixed on the reversing shaft. The valve of the steam cylinder is of the rotary pattern. There is a by-pass valve on the hydraulic cylinder, worked by a continuation of the stem of the steam valve. These valves are worked by a system of differential levers, the primary motion being derived from the hand lever on the working platform and the secondary motion from a pin on the reversing arm; all parts are so adjusted that the reversing engine follows the motion of the hand lever and all parts are firmly held when stopped. There is a stop cock in the by-pass pipe of the hydraulic cylinder, and a pump for reversing by hand connects to the hydraulic cylinder with its lever convenient to the working platform. The hand arrangement is always in gear.

Each main engine is fitted with a double turning engine. This engine drives a horizontal shaft on which is a worm that drives a vertical shaft. This vertical shaft has near its bottom end a worm which may be made, at will, to mesh with a bronze worm wheel on the propelling shaft. The vertical shaft is squared at the end to fit a ratchet by which the engine may be turned by hand.

The working platforms are inboard of the engines and communication between the engine rooms is possible through a vertical watertight door in the central bulkhead. All working parts of the machinery are fitted with efficient lubricators.

ENGINE DATA.

Cylinders, number for each engine	4
H.P., diameter, inches	35¼
I.P., diameter, inches	53
L.P., diameter, inches (two)	63
Stroke of all pistons, inches	48
H.P. valves (piston), diameter top, inches	18¼
bottom, inches	18
I.P. valves (slide), length, inches	56 1/16
width, feet and inches	5- 1
L.P. valves (slide), length, inches	56 1/16
width, feet and inches	5-11
Valve stems, diameter at stuffing box, inches	3½
below stuffing box, inches	3¼
through valve, inches	2½
I.P. and L.P. valve stems, diameter at balance pistons, inches	2
Main steam pipe, diameter at throttle, inches	13
area of cross section, square inches	132.73
Volume swept by H.P. piston, mean, per stroke, cubic feet	26.86
I.P. piston, mean, per stroke, cubic feet	60.7
both L.P. pistons, mean, per stroke, cubic feet	171.90
Clearance of H.P. cylinder, per cent. top, 18.8 ; bottom,	15.7
I.P. cylinder, per cent. top, 14.09 ; bottom,	11.93
F.L.P. cylinder, per cent. top, 13.5 ; bottom,	11.88
A.L.P. cylinder, per cent. top, 13.6 ; bottom,	11.88
Net area of I.P. to H.P. piston	2.257 to 1
both L.P. to H.P. piston	6.4 to 1
Piston rods, diameter, inches	7⅛
diameter of axial holes, inches	1½
length, feet and inches	9- 6½
Cylinder walls, H.P., I.P. and L.P., thickness, inches	1½, 1⅜, 1⅜
liners, H.P., I.P. and L.P., thickness, inches	1⅜
Valve chest liners, thickness, inches	1½
Jacket space, inches	⅝
Cylinder relief valves (one each end each cylinder), diameter, in.,	3½
Connecting rod, length, center to center, inches	96
diameter, upper end, inches	7¼
lower end, inches	8¼
axial hole, inches	5
crosshead bolts (4), diameter, inches	3¼

Connecting rod crank-pin bolts (2), diameter, inches	4¼
Crosshead, surface, ahead, square inches	495
backing, square inches	275
pin, diameter, inches	9⅝
of conical axial hole, inches	7 to 3
length of pin, inches	9½
Crank shaft, number of sections	4
diameter, inches	16
of axial hole, inches	8½
coupling discs, inches	27
coupling bolts, number in one flange	8
diameter, inches	3
journals, diameter, inches	15½
length, inches	17
length of sections, feet and inches	9- 2½
maximum distance beyond journals, feet and inches	2-10⅝
Crank pin, diameter, inches	15½
length, inches	16½
projected area, square inches	248
diameter of axial hole, inches	8½
webs, width, inches	17
thickness, inches	9½
Thrust shaft, diameter, inches	15
axial hole, inches	8½
collars, number on each shaft	12
diameter, inches	23
thickness, inches	2½
space between, inches	4½
total surface, both engines, square inches	2,794
length, feet and inches	14
steady bearings, inches	24
Line shaft, diameter, inches	14⅝
axial hole, inches	8½
coupling discs, inches	31
coupling bolts, in one flange, number	6
diameter, inches	3⅝
length, feet	32
Propeller shaft, diameter over liners, in strut bearings, inches	17½
after stern-tube bearings, inches,	18
diameter in forward stern-tube bearings, over liners, inches,	18
length, feet and inches	49- 4 1/16
Inboard collar coupling, diameter, inches	31
length, inches	24½
of collar, inches	17½

Stern bracket bearing, diameter, inches	$17\frac{9}{16}$
length, feet and inches	4– $1\frac{1}{2}$
Reversing engine, diameter of steam cylinder, inches	16
controlling cylinder, inches	$8\frac{1}{2}$
stroke, inches	$20\frac{1}{2}$
Turning engine, diameter of steam cylinders (2), inches	6
stroke of pistons, inches	6

Shafting and Bearings.—There are four sections of crank shafts for each engine, made of forged nickel-steel, oil tempered and annealed, all interchangeable. Each section has a crank of 24 inches throw. There are raised seatings on each section of shafting for the eccentrics. The sequence of the cranks is: H.P., I.P., F.L.P., A.L.P.; the H.P. and F.L.P. cranks are opposite, as also are the I.P. and the A.L.P.; the second pair are at right angles with the first pair. A worm wheel for turning the shaft is fitted on the forward end of each crank shaft.

There is one section each of thrust, line and propeller shafts for each engine. The line shaft is 32 feet long and is supported by two spring bearings.

The thrust bearings are of the horseshoe pattern. The pedestals are of cast iron; the ends and side walls of each form an oil trough. Each end forms a bearing for taking the weight of the shaft and is lined with white metal and fitted with a cap. There are eleven horseshoes made of composition, lined with white metal, properly channeled for oil, and secured by collars on steel side rods, $3\frac{3}{4}$ inches in diameter. There is an oil cup in the top of each horseshoe, from which an oil hole leads to each collar. At each end of each thrust bearing there is a divided stuffing box and gland of brass fitted to prevent the escape of oil. The oil trough has a circulating pipe for cooling water. The pedestal is bolted to a cast-iron soleplate, fitted with forged-steel wedges at each end of the pedestal for adjusting the bearing fore and aft.

The propeller shafts are covered with a composition watertight casing, shrunk and pinned on. This casing extends from within 19 inches of the forward coupling to 1 inch inside of the propeller hub. The casing makes a watertight joint with the

propeller hub. The inboard coupling consists of a forged-steel collar, secured by three steel keys. Back of this collar is fitted another collar in halves, and secured to it and to the coupling on the line shaft by six $3\frac{3}{4}$-inch fitted steel bolts.

There is a bearing in each end of each stern tube. These bearings consist of a composition bushing made in halves and fitted with sections of lignum-vitae, fitted to wear on end of grain. There is a composition stuffing box, made in halves, at the forward end of each stern tube. Each stern bracket has a lignum-vitae bearing, fitted as in the stern tubes.

Main Condensers.—There is one main condenser for each main engine. The shells are of steel, in four sections, $\frac{7}{16}$ inch thick, flanged and riveted. The longitudinal seams are lap welded; flange steel rings are riveted around each end to form flanges for securing the water chests. The water chests are of composition, cast $\frac{1}{2}$ inch thick; each contains six 10-inch manholes fitted with composition covers. The water chest for the entrance and exit of circulating water has a division plate fitted with valves worked by a lever on the outside of the condenser to allow the circulating water to pass overboard direct when the valves are open. The inlet and outlet nozzles are each 18 inches in diameter of opening.

The tube sheets are one inch thick, of rolled Muntz metal. The tubes are seamless-drawn Muntz metal (Government composition) and are tinned inside and out. The tubes are packed with cotton tape covered with graphite, brass screw glands, fourteen threads per inch, being used. The glands in the upper half have a small cross of brass between each pair. The horizontal arms of these crosses fit in the wrench slots of adjoining glands and act as keys to prevent the glands from unscrewing.

Composition nozzles, riveted to the top of each condenser, contain the following openings:

Two for main exhaust pipes, each 24 inches in diameter.

One for auxiliary exhaust pipe, 9 inches in diameter.

One for bleeder valve, 5 inches in diameter.

One for salt-feed pipe, 2 inches in diameter.

There are also the following openings:

One for air-pump suction pipe, 12 inches in diameter.

One manhole at bottom, 14 inches in diameter, fitted with a 2-inch nozzle for boiling out the condenser.

One hand hole in bottom of each tube sheet, 7 inches × 3¾ inches.

One 1¼ inch opening for reversing engine exhaust and one 3½ opening for cylinder drains.

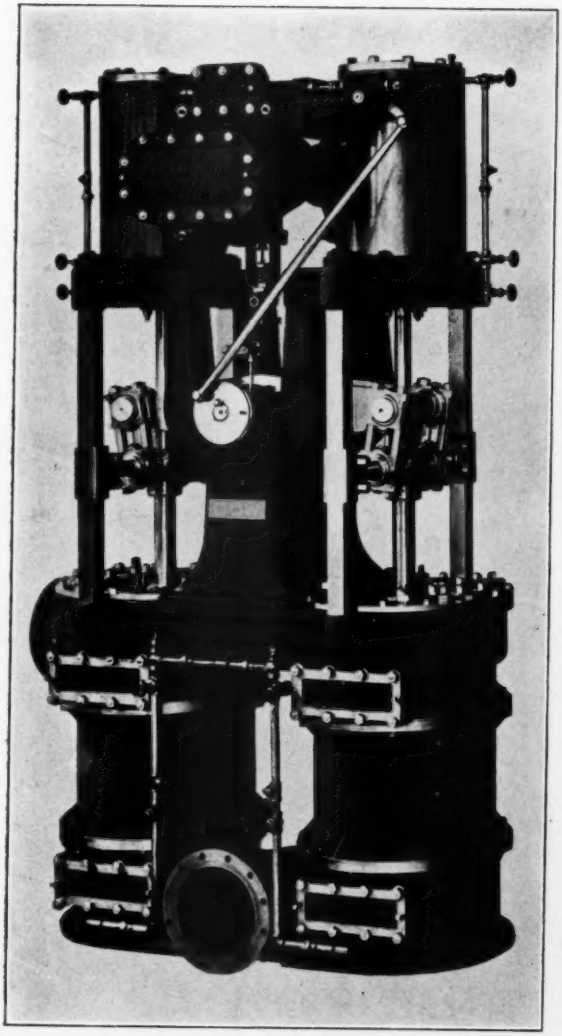
One man hole (or sight hole), 12 inches in diameter, near top of shell.

Baffle plates of steel are fitted to direct the steam over all the tubes. Drain cocks are fitted with pipes leading to the bilge.

Diameter of shell inside, feet and inches	6– 8
Thickness of shell, inch	1⅞
Length over heads, feet and inches	13– 7¼
Tubes, diameter (outside), inch	¾
length between tube sheets, feet and inches	11–10
thickness, No. 18 B. W. G., inch	.048
spacing between centers, inch	1⅛
number in each condenser	4,769
Condenser, cooling surface (each 9,040 square feet)	18,080

Main Air Pumps.—In each engine room there is one vertical, twin-beam, air pump, manufactured by the Geo. E. Dow Pumping Engine Company, San Francisco, California. The pump consists of two steam and two air cylinders. The steam cylinders are above the air cylinders, the axis of each air cylinder being in line with its steam cylinder. The piston rod and pump rod have a common crosshead to which they are secured by pins. The cylinder supports form slides for the crossheads. The twin beam extends from crosshead to crosshead. The valve motion is derived by means of suitable rods from a pin eccentrically placed on the shaft of the beam. One rotary valve operates both steam cylinders.

The air cylinders have a common suction from the condenser, 12 inches in diameter, and a common discharge to the feed tank, 12 inches in diameter. There are 18 valves in each suction chamber, 15 in each bucket, and 15 in each delivery chamber.



MAIN AIR PUMP, U. S. S. "OHIO".

The buckets are made of composition and are packed with composition rings. The steam cylinders are of cast iron and the air cylinders of composition. The valves, all 3½-inch opening, consist of three phosphor-bronze discs. The piston rods are of forged steel and the pump rods of Tobin bronze.

Diameter of steam cylinders, inches	12
air cylinders, inches	25
Stroke, inches	20
Diameter of piston rods, inches	2¼
pump rods, inches	3
valve openings, inches	3½
Number of suction valves, each cylinder	18
delivery valves, each cylinder	15

Main Circulating Pump.—In each engine room there is a centrifugal, double-inlet circulating pump driven by a compound engine with cranks at 90 degrees to each other. The high-pressure valve for circulating engine is a piston valve and the low-pressure is a slide valve. Each pump is designed to discharge 12,000 gallons of water per minute from the bilge, revolutions not exceeding 260 per minute.

Each pump is so connected that it may draw water from the sea through an 18-inch valve, from the main drain through a 14-inch valve or from the engine room bilge through a 20-inch valve. These three valves cannot be opened without inserting a key, one of which is supplied in each engine room. When a valve is open the key cannot be removed, so it is impossible to open more than one of these injection valves at once. The pumps discharge into the main condensers on their respective sides. When the valves in the division plate in the water chest at the injection end of the condenser are open the circulating pump discharges directly overboard.

In the sea injection pipe leading to the condenser is a wedge section fitted with a bonnet. By removing the bonnet and inserting a plug kept on the engine-room bulkhead the main injection pipe is completely blocked off and any part of the line inboard may be overhauled without regard to the Kingston valve.

Diameter of H.P. cylinder, inches	9
L.P. cylinder, inches	17
Stroke, inches	10
Diameter of pump runner, inches	38
Width of pump runner at periphery, inches	3½
hub	8
Diameter of inlet nozzle, inches	20
outlet nozzle, inches	18

Feed and Filter Tanks.—In each engine room there is a combined feed and filter tank. Each feed tank has a capacity of about 2,200 gallons, exclusive of any dead water, and each filter tank has a capacity of about 600 gallons. These tanks are directly under the main condensers, the filter compartments being above the feed tank.

The feed tanks are of ¼-inch galvanized steel, well braced internally and covered with cow-hair felt and lagged with galvanized steel. Each tank has 250 inches of standard rolled-zinc plates, suspended from braces. These tanks are fitted with an overflow pipe, with spring-loaded valve, leading to the bilge, and so arranged that any water passing through it may be seen. Each tank has a 14-inch manhole, an 8-inch feed-pump suction and a 3-inch vapor pipe which discharges above the level of the awnings. The tanks are also fitted with the usual connections, such as gauge-glass fittings, drain, etc.

Above each feed tank, made in one with it, of ¼-inch galvanized steel covered with cow-hair felt and lagged with galvanized steel, are three compartments filled with Loofa. The compartments are fitted with bolted covers which give ready access to the Loofa. The discharge from the main air pumps, 10 inches in diameter, leads into the forward compartment. The compartments are so fitted with plates that the water passes down through the Loofa in each compartment, one after the other, and then into the feed tank. This filter arrangement worked excellently on the trial. A very large quantity of oil was used on parts of machinery from which it could get into the exhaust steam, and an examination after the trial showed that the Loofa had absolutely prevented any of it from entering the feed tank. The Loofa, especially that in the first compartment, was full of oil.

The feed pump suctions are fitted with a balance valve operated by a copper float in the feed tank, so arranged that it allows no air to enter the feed pipes and so fitted that it may be worked from the outside.

Feed Pumps.—The main and auxiliary feed pumps were made by the Geo. E. Dow Pumping Engine Company, San Francisco, California. They are of the vertical, piston, double-acting type. There are two main feed pumps, one in each engine room, and four auxiliary feed pumps, one in each boiler compartment. The main feed pumps are each capable of delivering 640 gallons per minute, and draw water from the feed tanks and deliver into the main feed line. They take steam from either the main or the auxiliary steam line.

The auxiliary feed pumps draw from the feed tanks, the sea, the drainage system, the fireroom bilge, or the boilers in their compartments. They are arranged to discharge into the boilers, into the fire main, or overboard through sea valves in their own compartments, and to take steam from the auxiliary or main line.

Main feed pumps, number	2
Diameter steam cylinder, inches	16
water cylinder, inches	12¼
piston rod, inches	2¼
pump rod, inches (Tobin bronze)	2¼
Stroke, inches	18
Auxiliary feed pumps, number	4
Diameter, steam cylinder, inches	14
water cylinder, inches	10
piston rod, inches	2¼
pump rod, inches (Tobin bronze)	2¼
Stroke, inches	18

Pumps in the Engine Rooms.—The hotwell pumps, one in each engine room, are the same in all respects as the main feed pumps. The fire and bilge pumps and the water service pumps, one of each in each engine room, are the same in all respects as the auxiliary feed pumps.

The hotwell pumps are fitted to draw from the reserve fresh water bottoms, the feed tank, the air-pump channel ways, or from

the sides of the ship above the water line for taking in fresh water. They discharge into the feed tank or into the main feed-pump suction. The fire and bilge pumps are fitted to draw from the engine-room bilges, the main drain, the secondary drain, or from the sea and discharge overboard or into the fire main. The water-service pump draws from the sea and discharges into the engine water-service or flushing system.

From the fire main, by means of suitable valves and piping, water may be sent into the flushing system or into the distillers. From the water service water may be sent into the fire main.

On each main engine are two pumps worked by a common eccentric. These pumps draw from the crank pits, the main drain or the secondary drain, and discharge overboard.

Feed-Water Heaters.—The body of the feed-water heaters, one of which is placed in each engine room is cylindrical in form and of sheet steel, $\frac{5}{16}$ of an inch thick, $35\frac{1}{2}$ inches diameter. At one end, bolted to a composition flange which is riveted to the shell, is a composition tube sheet. At the other end the composition tube sheet is secured to the flange by an expansion joint. Water heads are formed by composition plates, bolted to suitable flanges on the tube sheets. In each heater there are 394 1-inch Muntz metal tubes, 8 feet long, No. 10 B. W. G., expanded into each tube sheet. The feed water enters a nozzle at bottom of stationary water head, passes through lower nest of tubes, up through movable head and then back through upper nest and out through a nozzle to the feed line. Steam enters the shell from the auxiliary exhaust line through a 9-inch nozzle near the top, and after passing around the tubes is trapped off. A small single-acting pump is fitted to drain from the feed-water heater trap and discharge to feed tank. The total heating surface of the tubes is 800 square feet for each heater. Each heater is fitted on its steam side with a combined pressure and vacuum gauge. An automatic constant-pressure regulator valve in the auxiliary exhaust line keeps the steam pressure in the heater constant.

Auxiliary Condensers.—In each engine room there is an auxiliary condenser. The shells and heads are of composition and the tube sheets of rolled Muntz metal. The condenser has the

usual cylindrical form, the tubes are packed as in the main condenser, and the condenser is of the following dimensions:

Diameter of shell (inside), feet and inches	2-9
Thickness of shell, inches	$\frac{1}{2}$
Length over heads, feet and inches	6-9$\frac{1}{2}$
Tubes, diameter (outside), inches	$\frac{3}{4}$
length between tube sheets, feet and inches	5-8
thickness, No. 18, B. W. G., inch	.048
spacing between centers, inches	$1\frac{1}{16}$
number in each condenser	864
Condensers cooling surface, both, square feet	1,600

The auxiliary condensers are both fitted with a vertical combined auxiliary air and circulating pump of the Dow pattern.

Diameter of steam cylinder, inches	8
circulating-pump cylinder, inches	12
air-pump cylinder, inches	12
Stroke, common, inches	10
Air pump, kind of valves	rubber.

Screw Propellers.—The propellers, arranged to turn outboard when going ahead, are of the three-blade type, of manganese-bronze. The starboard propeller is right and the port propeller is left-handed. Each blade is firmly bolted to the boss by stud bolts, the bolt holes in the flanges being oval to allow of adjustment of the pitch. The space around these bolts was completely filled with chocks, after the blades were set, to prevent slipping.

Each boss is accurately bored to fit the taper on the after end of the shaft and is fitted with a feather key. The shaft casing enters about one inch into the boss and the joint between the two is watertight. The propellers are held on the shaft by a nut screwed on and locked in place. Each boss is fitted at the after end with a composition cap bolted on watertight; the bosses and caps are finished all over, tinned and smoothed. The blades are accurately balanced, smoothed, polished, tinned and again smoothed. The following table refers to the Union Iron Works propellers, used on trial:

Number of blades	3
Diameter of propeller, feet and inches	16-3
Pitch, feet and inches	17-3

Pitch, adjustable, feet and inches	16-3 to 18-3
Expanded area, square feet	90
Projected area, square feet	75
Pitch ratio	1 to 1.04
Ratio of total expanded blade area to immersed midship section (draught 23 feet 6 inches)	1 to 9.0277
Ratio of expanded blade area to disc area	41.5 to 100

Boilers.—There are twelve Thornycroft boilers placed in four watertight compartments, so arranged as to give one small and one large fireroom in each compartment. All generating tubes are of the same diameter.

In these boilers, which are of the usual Thornycroft battleship boiler type, an arch of firebrick extending the length of the furnace is placed a little below the point where the tubes from the center and wing lower drums begin to have the same direction. This arch acts as a baffle to the flame and hot gases, causing them to spread around the tubes instead of going straight up, and in this way prevents loss of heat. Gratings about the height of the steam drums form passageways between the firerooms.

Number of boilers	12
Steam drum, inside diameter, inches	48
thickness, inch	1
Water drums, inside diameter, inches	19
thickness, inch	$\frac{3}{4}$
Number of tubes, one boiler	1,210
Tubes, diameter, outside, inches	$1\frac{3}{4}$
gauge	B. W. G., No. 9
Grates, length, feet and inches	5- $9\frac{3}{4}$
width, feet and inches	6- 8
distance of top from center of water drums, inches	11
Effective heating surface, one boiler, square feet	4,437.76
grate surface, one boiler, square feet	77
Total heating surface, square feet	53,253.12
grate surface, square feet	924
Ratio of heating surface to grate surface	57.6
Working pressure, pounds per square inch	200
Safety valves (2), diameter, inches	$4\frac{1}{2}$
Sentinel valves, area, square inch	$\frac{3}{4}$
blowing off, pressure, pounds	202
Smoke pipes (3), diameter, feet	8
area each, square feet	50.26
total area, square feet	150.78

Smoke pipes, height above grates, feet and inches	85- 6
Forward escape pipe, diameter, inches	9
After escape pipes (2), diameter, inches	7

Forced Draft.—The Howden system of forced draft is fitted to all the boilers. On the midship bulkhead above the height of the steam drum a compound blower engine is placed. This engine drives a vertical fan so fitted as to take air from the fireroom on each side of its hub and to discharge inboard.

Above the steam drum is a box containing tubes running vertically from bottom to top. These tubes are so fitted that all the smoke and hot gases must pass through them before reaching the funnel. The front and back of the boiler are formed by air-tight channel ways which lead down from the tube box. These channel ways have openings above and below the grate surface. In the front the upper opening of the channel way is into the space between the two faces of the furnace door, the inner door being perforated, and in the back the upper opening is through perforated plate above the bridge wall. Dampers are fitted, working from the front of the boilers, which close or open the channel-way discharges.

The air drawn by the fan from the fireroom is forced through the tube box, where it is heated, then down through the channel ways, and is discharged above and below the grate surface.

Baffle plates are fitted at the fan discharge, which distribute the air around the tubes, and the tube box is so divided that air is forced through the front and back channel ways in about equal quantities.

Number of blowers	12
Type of blower engine	Vertical, inverted, compound, inclosed.
H.P. cylinder, diameter, inches	5
L.P. cylinder, diameter, inches	8
Stroke, inches	6
Diameter of piston rods, inches	1¼
fan, inches	60
Area of induction nozzle, square inches	1,608
eduction nozzle, square inches	1,608
Capacity per minute, 1 inch of water, cubic feet, approximately	24,000

Ash Hoists.—From the upper deck down the fireroom ventilators are square in section and are fitted with angle-iron guides for the ash buckets. Two-cylinder, vertical engines, 4-inch by 4-inch, 6-inch stroke, placed on the inboard side of the ventilators, operate the hoisting drums, around which are wire cables leading through suitable sheaves in the ventilators to the fire-rooms. The ventilators have watertight doors opening to the main deck through which the ash buckets are taken. Outboard on the main deck are two ash hoppers on each side.

The ash-hoist engines are each capable of hoisting 300 pounds from the fireroom floor to the main deck in five seconds with steam of 80 pounds pressure.

Distilling Plant.—The distiller room is on the berth deck amidships, just forward of the engine-room hatch and opening into the same. There are four evaporators and two distillers having a combined capacity of 16,000 gallons of potable water per twenty-four hours at a temperature of not more than 90 degrees Fahrenheit. Each evaporator has a heating surface of 200.98 square feet and each distiller has a cooling surface of 89 square feet. The evaporators take steam from the auxiliary steam pipe. The following is an extract from the report of the machinery trial board: "As located at present the distillers cannot be readily examined and overhauled. We recommend that they be installed in the engine-room hatch. A short trial of the distilling plant made by the Board shows that it will probably be necessary to install a third distiller."

The evaporators are arranged two on a side, and each pair may be operated with compound effect. Each pair has a small feed pump of the vertical Dow type, and each distiller drain tank has a small vertical, fresh-water Dow pump. The distilled water may be run by gravity into the reserve fresh-water bottoms or pumped into the forward fresh-water tanks. A single, vertical, Dow pump on the main deck forward is used to pump water from the fresh-water tanks into the gravity tanks throughout the ship. The distiller circulating water is taken from the fire main.

Engineer's Workshop.—The engineer's workshop is on the berth deck, just abaft and opening into the engine-room hatch.

A 6-inch by 5-inch vertical inverted engine, fitted with fly wheel and automatic governor, is provided to drive the tools and a 5-H.P. electric motor is provided to drive the large gap lathe.

The following tools are provided and installed in the shop:

Gap lathe, 24-inch, back geared, 8 feet between centers.

Small lathe, 14-inch, back geared, 3 feet between centers.

Column shaper, 15-inch stroke, 24-inch traverse.

Two 12-inch emery wheels.

Drill, back geared, 1½-inch drill.

Sensitive drill.

Work bench with vises.

A portable combined hand shear and punch is also provided.

Ice Machine.—On the starboard side of the berth deck, just forward of the diagonal armor is one Allen dense-air ice machine, capable of producing the cooling effect of two tons of ice per day. It has cooling pipes to the ice tank, the cold storage and the scuttle butt.

Cylinder, steam, diameter, inches	9½
compressor, diameter, inches	7
expander, diameter, inches	5½
Stroke, inches	13
Piston rods (3), diameter, inches	1¾

Windlass, Winches, Etc.—The windlass is of the Hyde type, suspended from the upper deck, forward of the forward turret. It has two 15-inch steam cylinders and a stroke of 14 inches.

In the windlass box is a worm-gear winch having two steam cylinders 6 inches in diameter and 8-inch stroke. This winch has two gypsies, one 18-inch and one 30-inch. At 100 pounds steam pressure, 440 revolutions, the strain on rope for 18-inch gypsy is 13,700 pounds, speed 89 feet per minute; for 30-inch gypsy, 8,200 pounds, speed 148 feet per minute.

Three coaling winches are provided. Two are placed on the upper deck, starboard and port, between the two forward smoke-pipes, and one on the bridge deck aft, above junior officers' bath-room. Strain on rope for these winches, 2,200 pounds; speed, 300 feet per minute. The diameter of the two steam cylinders and their stroke is 8 inches.

Abaft the after turret on quarterdeck is a winch with same size of steam cylinders and same stroke as coaling winches, but it is double geared. One gear gives pull of 2,200 pounds at 300 feet per minute and the other 13,200 pounds at 50 feet per minute.

Two electric boat cranes are fitted, one on either side of the bridge deck, between the two after smoke pipes.

Steering Engine.—The steering-engine gear is hydraulic, of the Union Iron Works type, and is similar to that fitted on the *Olympia*, *Oregon* and *Wisconsin*. Two hydraulic, vertical, duplex, differential pumps, one in each engine room, give the required pressure of 600 pounds per square inch in the two 14-inch steering-engine cylinders.

Steam cylinders, pumps, diameter, inches	10
Water cylinders, pumps, diameter, inches	4½ and 3
Stroke, inches	12
Diameter of piston rod, inches	1¾

Boats.—The following boats of Bureau design are supplied:

1 Steam Cutter, 40 feet.
1 Steam Cutter, 36 feet.
2 Sailing Launches, 36 feet.
4 Cutters, 30 feet.
2 Whaleboats, 30 feet.
1 Gig Whaleboat, 30 feet.
1 Barge, 30 feet.
2 Dinghys, 20 feet.
1 Dinghy, 16 feet.
2 Balsas, 18 feet.
2 Punts, 12 feet.

Air Compressors.—One air compressor, of the Rand type VI, driven by a 25-H.P. motor, is installed in the torpedo room.

The Bureau of Ordnance has now under consideration the installment of a gas expelling device for each turret, which, if installed, will require an independent air compressor and reservoir for each turret.

The following is an extract from the report of the Machinery Trial Board: "An air compressing plant would be a great aid in keeping the boilers of the type used on the *Ohio* clean and in good condition."

Electric Plant.—The electric generating plant consists of four 32-kilowatt and four 50-kilowatt generating sets, a total of 328

kilowatts, or about 430 electrical horsepower. The generating sets were built by the Union Iron Works, the engines being of the vertical, inverted cylinder, compound type, direct connected to multipolar generators.

32-KILOWATT ENGINES.

Cylinder, H.P., diameter, inches	8½
L.P., diameter, inches	13½
Piston rod, diameter, inches	1¾
Stroke, inches	8
Speed, revolutions per minute	400

50-KILOWATT ENGINES.

Cylinder, H.P., diameter, inches	10
L.P., diameter, inches	16½
Piston rod, diameter, inches	2
Stroke, inches	10
Speed, revolutions per minute	350

The 32-kilowatt generators are of the four-pole type, designed for a normal output of 400 ampères with 80 volts at the terminals. The 50-kilowatt generators are of the six-pole type, designed for a normal output of 625 ampères at 80 volts. The normal steam pressure for generating engines is 100 pounds. The test showed a combined efficiency of the sets of about 85 per cent.

The generating sets are installed in pairs in four dynamo rooms which occupy the space below the protective deck immediately forward of the forward boiler spaces. There are two upper and two lower rooms; the upper contains the 32-kilowatt sets and the lower the sets of 50-kilowatt capacity. The main generator, light, power and searchlight switchboards are placed in the starboard upper dynamo room.

The electrical installation, apart from the generating sets, consists in general of about 850 incandescent lamps, four 30-inch searchlights, two Ardois night-signaling sets, two 150-candle-power diving lamps, four ¼-horsepower electric ventilating sets, forty $\frac{1}{12}$-horsepower and five ⅛-horsepower electric fans, one main generator lighting and power switchboard and one searchlight

switchboard, together with the necessary wiring, lamps, instruments, tools, etc., usually furnished.

In addition to the foregoing there are installed throughout the ship 122 motors representing a total capacity of about 516 horsepower. These motors furnish power for the various ammunition hoists, ventilating blowers, electrically-operated watertight doors and hatches, as well as for boat cranes, turret-turning machinery, torpedo air compressors and workshop machinery.

The ship is provided with an outfit for wireless telegraphy and with elaborate means for interior communication, signaling and the transmission of orders.

SPEED TRIAL.

The vessel left the Union Iron Works, San Francisco, California, for the trial course in Santa Barbara Channel on Thursday, July 28, 1904, and arrived at Santa Barbara the next day, July 29, 1904. As it was necessary to do some work on the bearings of the main engines and on the blowers, the trial was delayed until Monday, August 1, 1904.

On the run down to Santa Barbara a test of signals and of the system adopted for securing data was made to assure the data being taken as required. The periods for taking indicator cards were set to begin about seven minutes after the beginning of the trial, thus giving the observers in the engine room sufficient time to take the data at the start on each course.

The vessel started on the official speed trial over the official course at 7 h. 21 min. 40 s. A. M., and reached the end of the course at 9 h. 21 min. 1.0 s. A. M. The turn occupied 7 min. 55 s. The line was crossed on the return trip at 9 h. 29 min. 0.5 s. A. M., and the end of the course was reached at 11 h. 31 min. 50 s. A. M. The times here given were taken by the engine-room clock.

There was no difficulty in keeping up the steam pressure during the trial, although many of the fireroom force were not skilled firemen. There was no considerable variation of pressure. The use of an automatic electric-firing indicator contributed materially in attaining the very satisfactory results given by

the boilers, and the Machinery Trial Board has recommended that the device be adopted for vessels of the Navy having water-tube boilers. This device is particularly desirable with the arrangement of boilers on the *Ohio.*

The pressure at the engines was kept down by opening the passover valves to the second receiver, one of them being open nearly all of the time on the trial. About thirty extra lights were used in each engine room.

Although 2½ inches of air pressure was allowed, the highest observed pressure in the firerooms was 1.7 inches and the average for the trial was only .7 inch. The thickness of the fires was seldom more than from 6 to 8 inches.

The builders employed 155 men in the engineering department during the trial, 33 of whom were in the engine room. The absence of vibration was very marked.

Both the H.P. and I.P. indicators of the starboard engine becoming disabled early in the trial, only one complete set of satisfactory cards was taken from these cylinders. Iron cuttings from the main cylinders or piston rings got into the barrels of the indicators, and repeated attempts to get satisfactory cards were failures. Additional cards were taken on the run back to San Francisco, so that the indicated horsepower as given in the synopsis is very nearly correct.

All auxiliary machinery was indicated after the trial.

	Run West.	*Run East.*
Elapsed time, hours, minutes and seconds	1'59'30	2'02'45
hours	1'991	2'046
Total revolutions, starboard engine	14,791	15,231
port engine	14,777	15,210
mean of both engines	14,784	15,220.5
Average revolutions per minute of both engines	123.72	123.99
Mean speed, with tidal corrections, knots	17.8175	
Draught of vessel, mean, during trial, feet and inches,	23–5¾	
Displacement corresponding to this draught, tons	12,480	

PERFORMANCE—SYNOPSIS OF STEAM LOG.

Performance :	
Steam pressure at boilers (per gauge) pounds	203.2
S.H.P. steam chest (per gauge), pounds	197.8
P.H.P. steam chest (per gauge), pounds	199.1

Performance:	
Steam pressure at 1st receiver, S., absolute	89.95
P., absolute	86.31
2d receiver, S., absolute	34.86
P., absolute	35.59
Vacuum in condensers, in inches of mercury.....P., 26.1; S., 25.6	
Mean effective pressures in cylinders, pounds, per square inch:	
Main engines—starboard, H.P	61.75
I.P	40.25
forward L. P	17.95
after L.P	17.23
port, H.P	77.25
I.P	44.02
forward L.P	17.03
after L.P	16.88
Mean effective pressure, pounds per square inch on L.P. piston, equivalent to aggregate M.E.P. on all pistons, starboard	42.3
Mean effective pressure, pounds per square inch, on L.P. piston, equivalent to aggregate M.E.P. on all pistons, port	43.5
Auxiliary machinery (cards taken after trial):	
Revolutions per minute:	
Main engines.....S., 123.93; P., 123.86	
Pumps, air.....S., 49.5; P., 27.8	
feed, double strokes per minute	20.6
Blower engines (mean of all)	638
Speed of ship in knots per hour	17.8175
Slip of propeller in per cent. of its own speed based on mean pitch.....S., 15.6; P., 15.5	
Air pressure in ash pits, in inches of water	0.7
Indicated horsepower:	
Main engines—starboard, H.P	1,698.4
I.P	2,897.4
F.L.P	1,669.1
A.L.P	1,602.3
total	7,867.2
port, H.P	2,018.6
I.P	2,913.6
F.L.P	1,583.3
A.L.P	1,568.4
total	8,083.9
Air pump .....starboard engine, 9.97; port engine,	9.07
Circulating pump..... .starboard engine, 73.22; port engine,	78.42
Feed pumps (2 main)	97.88
Hot well pumps (2)	7.
Auxiliary condenser, air and circulating pump	3.
Fire and bilge pumps (2)	7.

Blower engines, 12 at 12.355 =	148.27
Dynamo engines, 1 — 32 kw. = 48.37 ; 1 — 50 kw. = 71.08	119.45
Collective of both main engines	15,951.1
main engines, air, circulating and feed pumps, and auxiliary engines in operation during trial	16,507.3
all machinery during trial, per square foot of G.S.	17.85
H.S.	0.309
Main engines, air, circulating and feed pumps, per square foot of G.S.	17.54
Main engines, air, circulating and feed pumps, per square foot of H.S.	0.304
Coal—kind and quality	Harris Deep Navigation, hand picked, excellent.
pounds per hour	32,637
I.H.P., collective, all machinery in operation	1.97
main engines, air circulating and feed pumps,	2.01
hour, per square foot of G.S.	35.32
H.S.	.61
Cooling surface, square feet per I.H.P.	1.09
Heating surface, square feet per I.H.P., collective, all machinery,	3.22

An examination of the machinery after trial, and the return to San Francisco, showed that the machinery and boilers were generally in good condition. The high-pressure cylinders showed some wear, were slightly scored, and their piston packing rings were badly worn. One packing ring in each high-pressure piston was found broken.

The actual time to put the rudder over in the trial of the steering engine, as indicated by the mechanical indicator in the steering engine room, was:

	Seconds.
Amidships to hard-a-starboard	35
Hard-a-starboard to hard-a-port	58

The Trial Board states that "for practical purposes the *Ohio's* (steering) gear is considered satisfactory."

TEST OF A NICLAUSSE BOILER UNDER FORCED DRAFT.

By Commander W. M. Parks, U. S. Navy, Member.

The following tests of a Niclausse boiler of the Improved Marine Type were made at the works of the makers, the Stirling Company, at Barberton, Ohio, by a Naval Board consisting of Captain J. A. B. Smith, U. S. Navy; Commander W. B. Bailey, U. S. Navy, and Commander W. M. Parks, U. S. Navy.

The principal object of the tests was to determine whether the proportions of the boiler were such that it could be forced to a high rate of coal combustion without injury. Careful data were also taken to determine the efficiency of the boiler at the various rates of combustion.

THE BOILER.

The Board first carefully examined the boiler to be tested, and inspected the arrangements made for the tests. The boiler, as shown in Fig. 1, is of the Niclausse Marine Type as modified and improved by the Stirling Company, and is composed of wrought steel, twelve sections or headers wide. Each section or header is formed from a seamless steel pipe and contains twenty-four generating tubes $3\frac{1}{4}$ inches diameter by 7 feet $5\frac{11}{16}$ inches long, measured from the furnace side of the header. The circulating tubes are of light steel secured in the usual manner. The lantern and generating tube are in one piece, a seamless cold-drawn steel tube. The boiler is 12 feet $\frac{1}{8}$ inch from floor to center of the 42-inch steam drum, and is 8 feet $2\frac{1}{4}$ inches wide across the casing. The total H. S. is 1,852.56 square feet, and the single grate has 45.225 square feet of surface. There are two furnace doors. The grate bars incline from front to rear parallel with the tubes. The distance from grate to first row of tubes is 3 feet. The boiler was tight, clean and in excellent condition. The workmanship is of the same excellent quality as

XU

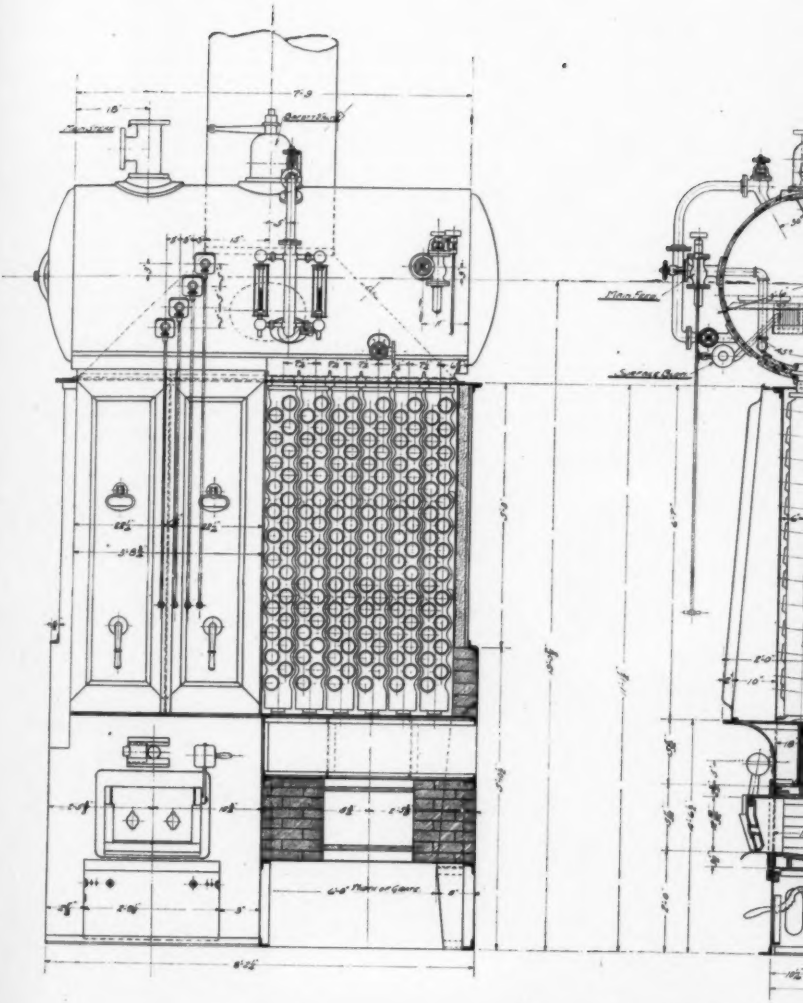
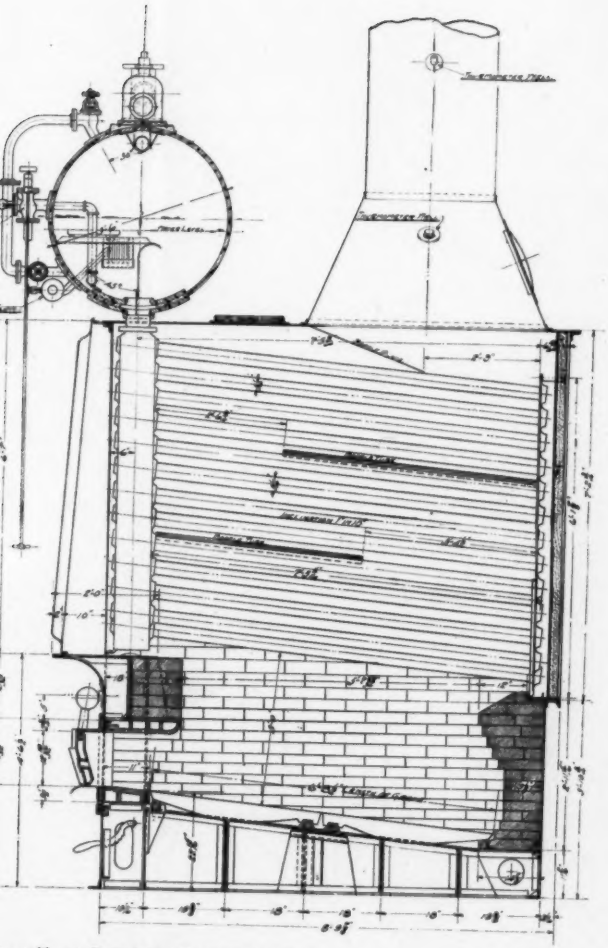


Fig. 1.—Niclausse Test Boil



Note.
Total Heating Surface = 1852.56 ft²
Total Grate Surface = 45.225 ft²

SSE TEST BOILER, MARINE TYPE.

shown in the boilers of the U. S. S. *Maine*. The boiler is baffled by tubes or pipes laid in the spaces between the circulating tubes, as shown on the drawing.

BOILER DATA.

Steam drum, diameter outside, inches	42
length over all, feet and inches	8–10¼
Length of tubes exposed, feet and inches	7– 5 11/16
Generating tubes per header, 3¼ inches, number	24
total number	288
Tube-heating surface per element, square feet	152.5
boiler, square feet	1,830
Header heating surface per boiler, square feet	22.56
Total heating surface per boiler, square feet	1,852.56
Length of grate, feet and inches	6– 8¼
Width of grate, feet and inches	6– 9
Grate surface per boiler, square feet	45.225
Ratio H. S. ÷ G. S.	40.96 to 1
Weight of water at 60° F., per element, pounds	583.3
per drum, 5¼ ins. water in glass, lbs.	1,682.76
per boiler, pounds	8,682.36
Total weight of boiler, dry, pounds	41,723.57
wet, pounds	50,405.93
Weight per square foot of H. S., dry, pounds	22.52
wet, pounds	27.20
Thickness of drum shell, inch	¾
head blank, inch	¾
manhole, inch	1
header, inch	7/16
tubes, No. B. W. G.	6
Height of combustion chamber, feet and inches	3– 0
Grate bars, kind, cast iron, marine standard:	
width of air spaces, inch	½
per cent. of air space	46.25
Smoke pipe, diameter, inches	39
area, square feet	8.29
height above grate, feet and inches	78 –6¾
ratio area to G. S.	1 to 5.5

Improved Niclausse Boiler.—The boiler tested is exactly like the boilers built by the Stirling Company for the battleships *Virginia* and *Georgia*, and the armored cruisers *Pennsylvania* and *Colorado*, except that the experimental boiler is 12 headers wide while the boilers for the ships named are each of 13 head-

ers to 16 headers wide. Also the boilers for the *Georgia* have a small steam dome on the steam drum, and have 6 inches greater depth of furnace space. The casing of the boiler tested is exactly the same as used on the boilers of the vessels named. The absence of doors in the casing is a noticeable feature, obviating loss by the inflow of air through buckled or badly fitted doors.

Before beginning the construction of the boilers for the battleships *Virginia* and *Georgia* and the armored cruisers *Colorado* and *Pennsylvania*, the resources of the Stirling Company were freely used in elaborate experiments to find out the proper proportion of headers, nipples, steam drums and other details for this type of boiler to render it safe and economical under conditions of forced draft. The important question of baffling was also investigated. The result has been the production of a boiler that retains little of the foreign type, save the principle and the general outline, and a boiler that these tests show to be safe, economical and durable under forced-draft conditions.

It is in the proportions of the headers that the greatest difference is shown between this boiler and the earlier boilers of the same type. Thus the area of header with tubes and lanterns in place is, for the *Maine's* boilers, down channel 8.76 square inches, up channel, 9.76 square inches. For the experimental boiler these areas are respectively 10.73 square inches, and 14.04 square inches. (See Fig. 2.)

Feed water for the boiler was taken from the town's water supply and was not heated.

The feed pump was a Worthington Duplex with outside packed plungers. Cylinders, steam end, 10 inches by 10 inches; water end, 6 inches by 10 inches.

There was a steam jet in the smoke pipe.

Arrangements for the Tests.—Tests had been made for several months past by the Stirling Company, so that the personnel was particularly well trained and efficient. The boiler was erected in an air-tight structure, built especially for the tests. There were two large air locks in the building, affording an easy means of passing to and from the fireroom without affecting the air pressure. The ground plan of the building is shown in Fig. 3.

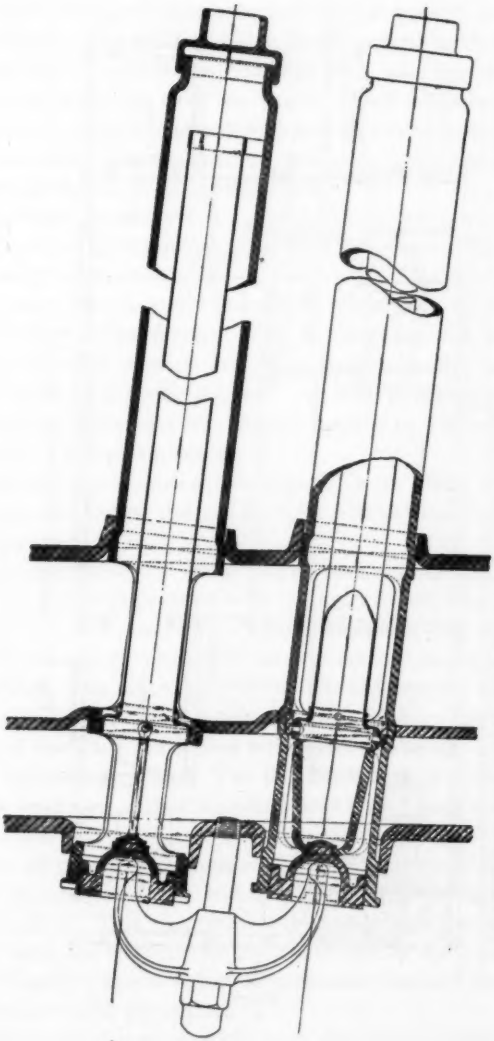


Fig. 12.—Details of Lanterns and Tubes. Niclausse Test Boiler, Marine Type.

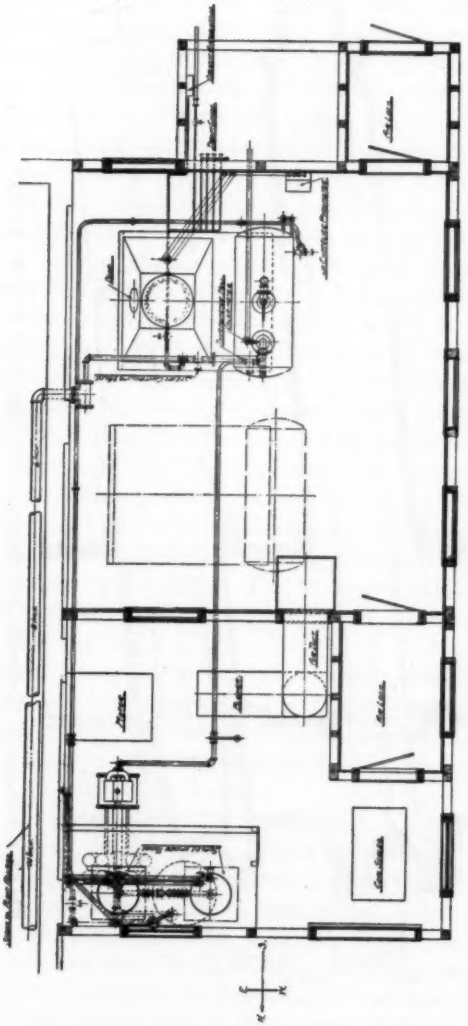


Fig. 3.—Ground Plan of Test House.

The blower for forced draft was of the Sturtevant fan type, 100 inches diameter, driven by belt from a 35-H.P. General Electric motor. The fan was driven at a constant speed of 546 revolutions per minute throughout the tests, and the draft was regulated by a sliding door on the fan inlet. The air was taken from the outside of the building and delivered into the fireroom near the top. The fan worked well and there was no difficulty in regulating the draft as required.

The steam pressure was controlled by a valve in main steam pipe worked by hand from the fireroom floor. The steam was delivered to the 6-inch steam main for the power plant of the works, and used to assist in running the various engines used by the Stirling Boiler Works. The power plant was kept running during the time of each test in order to use the steam and to avoid blowing off into the air. An emergency valve was fitted for blowing the steam into the air in case of having to stop the engines of the power plant.

The feed pump and weighing tanks were under cover, as was the place for taking the gas samples and the readings of various draft gauges.

All pipes by which water might escape from the boiler were disconnected and blanked with the ends in full view.

Scales, Instruments, Etc.—The Members of the Board saw all coal and water weighed and supervised the readings of all data recorded. The office force of the Naval Inspector of Machinery was called upon for assistance in this work. All scales used were of standard make and were carefully tested by the Board with standard weights. The thermometers, gauges and instruments were new and of standard make and had been carefully tested and calibrated.

The pyrometer used in base of smoke pipe was of the nitrogen-filled thermometer type, and extended about 20 inches into the smoke pipe. This pyrometer was used in first test only. On all other tests the temperature at base of smoke stack was taken by a Le Chatelier thermo-electric pyrometer checked and calibrated by the mercurial pyrometer.

Samples of gas were taken from the base of smoke pipe and analyses made by an Orsat apparatus.

The air pressure in furnace was taken from a pipe leading through the side casing and 24 inches above the grate. Ash-pit draft was taken from the sides of the ash pit 10 inches above the bottom.

Method of Weighing Coal.—The coal was weighed in barrows, the weights of empty barrows being carefully checked at intervals. The barrows were loaded with an even weight of 150 pounds of coal. The weighing was done outside the fireroom for all the tests, and the loaded barrows were wheeled into the fireroom through one of the air locks. At the end of each hour the fireroom floor was swept and the coal weighed back on all tests.

Method of Weighing Water.—Arrangements for weighing the water were made by having two elevated iron tanks, each on separate standard platform scales. The scales were tested before and during tests, and weights of empty tanks checked at intervals. The water was led from city main to each tank. After being weighed, the water was drained as required into a large feed tank placed below the other tanks. This latter tank was calibrated so that the water could be checked at any time. From the feed tank the water was sent to the boiler by the feed pump, through a feed pipe of $1\frac{1}{2}$ inches inside diameter. All parts of tanks, piping, etc., were in plain sight. At the end of each hour the actual amount of water was checked up and water in the upper tanks weighed back.

Quality of Steam.—For observing the quality of the steam a throttling calorimeter was used. The steam was taken from the vertical pipe from which all the steam was discharged from boiler at a point 9 inches above top of drum. The collecting nozzle was of standard pattern. The calorimeter was carefully calibrated by taking readings with pressure going up and down and no steam leaving boilers except through the calorimeter. From these standard readings the amount of moisture was calculated by the following formula:

$$Q = \frac{.48\ (T - t)}{L} \times 100,$$

in which Q equals percentage of moisture; T equals calibration reading of lower thermometer, 316 degrees Fahrenheit; t equals test reading of lower thermometer; L equals latent heat of steam at boiler pressure.

Moisture in Coal.—Samples of coal weighing about 50 pounds were carefully dried in a specially-prepared drying pan; the moisture determined by this method has been used in the calculations. Samples of coal for analysis were sent to the New York Navy Yard. Results are as shown on the analysis sheets.

Depth of Fires on Grates.—The depth of fires was judged by a member of the Board at the start and at the end of every hour, allowance being made for the probable amount of ash.

The Tests.—Five tests were made, using closed fireroom forced draft. The first three tests were of eight hours each, with air pressure of $\frac{1}{2}$ inch, 1 inch and $1\frac{1}{2}$ inches of water. The remaining two tests were of four hours each, the first with air pressure of 2 inches, and the last at a rate of combustion agreed upon, which was to be about 47 pounds per square foot of grate per hour. It was further agreed that the last two tests should be made on the same day with no interval of time between.

The coal used was Pocahontas of good quality, run of the mine, screened at the works of the Stirling Company. The coal had been at the works of the Company for about four weeks. The coal burned freely, leaving but a small per cent. of ash. After the tests, the grate bars, of standard Navy Type, were found to be perfectly clean and but little the worse for wear. Not a grate bar was lost during the tests and none was replaced. During all the tests, the casing was examined from time to time. On first test, the hand could be kept on any part of the casing. On second test, the sides and lower part of back were too hot to hold the hand on without discomfort. On the other tests the lower part of the back of casing was the same as on second test, but on the sides the hand could be placed without discomfort.

On all the tests one man tended water and regulated the steam pressure by means of the valve in main steam pipe. He appeared to have no difficulty with this work. The ordinary screw stop valve in feed main was used to regulate the supply of

feed water. The firing was done by one man on all the tests. A helper managed the furnace door for the fireman in order to keep the door open the least possible time.

A draft of $\frac{1}{2}$ inch as nearly as possible was maintained in smoke pipe by means of a steam jet, this being considered about the draft that could be expected when the boiler was on board ship.

The water level was remarkably steady during all the tests. The rate of combustion seemed to make no difference in steadiness of water level. There was absolutely no indication of spasmodic circulation or of reversal of the current of circulation.

After the last test the boiler was carefully examined and was found to be in good condition. The brick work and the casing generally was in good condition. Many of the baffling pipes were taken out and were found to be absolutely straight and not burned in the least. All the tubes of the three bottom rows and all the tubes of three middle headers, or 99 in all, were taken out in presence of the Board by two machinists and four helpers in 1 hour and 18 minutes. The tubes were tested with a straight edge, and all were perfectly straight except two very slightly bent. With all tubes out of the three middle headers the inspection of the other tubes on both sides of the vacant space was easily made by going from the furnace up to the base of smoke pipe, and then out through a manhole in the breeching. Inspection of the tubes remaining in the boiler as well as inspection of all baffling was made in the above mentioned manner.

Smoke.—Reports having been made concerning the great volume and density of smoke from the Niclausse boilers of the U. S. S. *Maine*, the Board particularly observed the quantity and quality of the smoke as it came from the top of the smoke pipe of the experimental boiler during these tests. It was found that the quality and quantity of smoke could be regulated in a great measure by the method of firing. A thick fire, with infrequent firing, as is usually the custom in firing Scotch Boilers, produced less perfect combustion with consequent volume of thick smoke. The method of firing the experimental boiler was frequent and

light firing carrying fires about six inches thick, and as even as possible. The furnace door was kept open the least possible time. The Board believes that, with this method of firing, the smoke from the experimental boiler was not in excess of that from any other water-tube boiler fired under the same conditions of coal and rate of combustion. Skill and expertness of the fireman is absolutely necessary with water-tube boilers to keep the smoke within ordinary limits. The method of baffling also has a part in the prevention of smoke, but the greatest factor entering into the question of smoke, is the human factor, the fireman. The firemen for water-tube boilers must be properly trained for the work, and there must be close and skilled supervision of their work in the fireroom. Regular and systematic firing is an absolute necessity with water-tube boilers.

FUEL AND GAS ANALYSES.

PROXIMATE ANALYSIS OF FUEL.

.....	Coal, per cent.				Combustible, per cent.			
TEST NUMBER.....	1	2	3	4-5	1	2	3	4-5
Date, July.....	25	26	27	28	25	26	27	28
Fixed carbon.....	75 31	78.22	77.96	79.8	80.22	82.18	81.77	83.
Volatile matter.....	18.57	16.96	17.38	16.34	19.78	17.82	18.23	17.
Moisture.....	.97	1.02	.82	.82	...	...	...	...
Ash.....	5.15	3.80	3.04	3.04	...	...	...	...
Total.....	100.	100.	100.	100.	100.	100.	100.	100.
Sulphur separately determined.....	.56	.49	.53	.47	...	...	...	...

ULTIMATE ANALYSIS OF DRY FUEL.

Carbon (C).....	85.18	85.63	86.46	87.	89.83	89.02	89.85	89.74
Hydrogen (H).....	5.07	4.86	4.86	4.76	5.36	5.07	5.06	4.92
Oxygen (O).....	2.62	3.4	2.86	3.38	2.76	3.55	2.99	3.48
Nitrogen (N).....	1.36	1.78	1 47	1.33	1.45	1.85	1.55	1.37
Sulphur (S).....	.57	.5	.54	.47	.6	.51	.55	.49
Ash.....	5.2	3.83	3.81	3.06	...	...	...	...
Total.....	100.	100.	100	100.	100.	100.	100.	100.
Moisture in sample of fuel as received	.97	1.02	.88	.82	...	...	...	...

CALORIFIC VALUE OF FUEL BY PARR STANDARD CALORIMETER AND BY ANALYSIS.

TEST NUMBER.....	1	2	3	4-5
Calorific value by calorimeter per pound of dry coal, B.T.U.....	14,192	14,750	14,502	14,502
combustible, B.T.U.....	14,960	15,330	15,070	14,960
analysis per pound of dry coal, B.T.U.....	15,134	15,018	15,191	15,176
combustible, B.T.U.....	15,950	15,620	15,790	15,630

TEST No. 1, CLOSED FIRE ROOM,

July 25, 1904.	A. M.					
	9·00	9·30	10·00	10·30	11·00	11·30
Steam pressure, gauge, pounds	266	272	276	274	275	276
Water in gauge glass, inches	3½	...	5½	...	6¾	...
Calorimeter, T_1, upper thermometer	404	405	405	407	407	408
T_2, lower thermometer	313	314	314	314	314	314
Q, water in steam, per cent	...	...	.116	...	.116	...
Gauge pressure at reading, inches	265	270	276	277	275	273
Temperature of feed water, degrees, F	74	74	74	74	74	74
outside air, degrees, F	73	74	74	76	76	77
fire room, degrees, F	87	88	89	89	92	92
gases at base of stack, degrees, F.	448	518	495	450	500	554
Draft pressure, inches water; ash pit	+.5	+.5	+.5	+.5	+.5	+.5
fire room	+.5	+.5	+.5	+.5	+.5	+.5
furnace	−.34	−.30	−.30	−.27	−.31	−.25
base of stack	−.48	−.55	−.55	−.54	−.54	−.53
Flue gases, CO_2, per cent	...	...	11.0	...	10.5	...
O, per cent	...	...	8.1	...	8.8	...
CO, per cent	...	...	0.0	...	0.0	...
Coal per hour, pounds	...	...	750	...	1050	...
total, pounds	...	...	...	...	...	...
Feed water per hour, pounds	...	...	9160	...	9203	...
total, pounds	...	...	...	...	...	...

Fires judged same thickness at end as at start (6½ inches), including about 1½ inch ash. Therefore 264 pounds must be added to the coal as found above, making total coal 7,797 + 264 = 8,061 pounds. Moisture in coal, 2.7 per cent.
Coal, Pocahontas, run of mine, screened.

TEST No. 2, CLOSED FIRE ROOM,

July 26, 1904.	A. M.					
	9·00	9·30	10·00	10·30	11·00	11·30
Steam pressure gauge, pounds	275	276	275	276	277	279
Water in gauge glass, inches	2¾	...	4	...	5	...
Calorimeter, T_1, upper thermometer	407	408	406	406	405	408
T_2, lower thermometer	314	314	313	313	313	314
Q, water in steam, per cent	...	...	.174	...	.175	...
Gauge pressure at reading, inches	277	277	275	275	272	281
Temperature of feed water, degrees, F	74	74	74	74	74	74
outside air, degrees, F	78	81	81	82	86	86
fire room, degrees, F	93	93	97	100	101	100
gases at base of stack, degrees, F.	518	527	572	590	650	662
Draft pressure, inches water; ash pit	...	...	...	...	...	...
fire room	+1.0	+1.0	+1.0	+1.0	+1.0	+1.0
furnace	+.42	+.25	+.40	+.35	+.36	+.39
base of stack	−.53	−.55	−.51	−.54	−.56	−.53
Flue gases, CO_2, per cent	...	...	9.9	...	10.3	...
O, per cent	...	...	8.3	...	7.6	...
CO, per cent	...	...	.013	...	.05	...
Coal per hour, pounds	...	...	1500	...	1350	...
total, pounds	...	...	...	...	...	...
Feed water per hour, pounds	...	...	13563	...	13621	...
total, pounds	...	...	...	...	...	...

Fires judged 8 inches thick at start, 10 inches at end, including 2 inches ash.
Coal, Pocahontas, run of mine, screened. Moisture, 2.37 per cent.
Refuse, ash pit, 315 + grate, 281, = 596 = 4.14 per cent.

½ INCH AIR PRESSURE.

	P. M.										Average.
12·00	12·30	1·00	1·30	2·00	2·30	3·00	3·30	4·00	4·30	5·00	
280	277	275	273	277	275	278	275	278	282	278	275·7
5	...	4½	...	3⅜	...	5½	...	5½	...	3½	5
407	407	408	407	408	407	408	408	408	408	408	407
314	314	314	314	315	315	315	315	315	315	315	314·3
.117	...	.116	...	.058	...	.058	...	.058	...	...	...
278	275	276	272	279	275	279	277	279	281	278	275·6
74	74	74	75	75	76	76	76	76	76	76	75
77	79	80	81	81	81	81	81	81	81	81	78·5
93	93	94	95	97	96	97	96	96	97	97	93·4
536	536	554	518	545	572	572	550	558	581	574	533
+.5	+.5	+.5	+.5	+.5	+.5	+.5	+.5	+.5	+.5	+.5	+.5
+.5	+.5	+.5	+.5	+.5	+.5	+.5	+.5	+.5	+.5	+.5	+.5
—.22	—.21	—.18	—.12	—.12	—.11	—.10	—.12	—.10	—.05	—.06	—.183
—.55	—.57	—.56	—.50	—.52	—.54	—.52	—.52	—.53	—.48	—.49	— 526
10.6	...	11.8	...	11.5	...	11.3	...	11.7	...	11.5	11.24
7.4	...	7.0	...	7.3	...	7.8	...	7.6	...	7.7	7.7
0.0	...	0.0	...	0.0	...	0.0	...	0.0	...	0.0	0.0
900	...	1050	...	1050	...	900	...	1050	...	1047	...
...	...	...	...	...	...	...	...	...	...	...	7797
9357	...	9727	...	9593	...	9488	...	10672	...	9940	...
...	...	...	...	...	...	...	...	...	...	...	77140

Refuse = 354 pounds or 4.4 per cent. of all coal fired from starting tests.
Barometer, 29.34.
Weather, partly cloudy and warm, with light breeze.
Smoke, medium to black, in puffs when firing.

1 INCH AIR PRESSURE.

	P. M.										Average.
12·00	12·30	1·00	1·30	2·00	2·30	3·00	3·30	4·00	4·30	5·00	
278	276	280	275	274	277	276	275	275	279	280	276.9
3⅜	...	3	...	2½	...	4	...	4	...	2⅜	...
409	407	408	406	407	407	406	408	408	409	407	407.4
314	3'4	314	313	313	313	313	314	314	314	314	313.6
.117	...	.117	...	.175	...	.175	...	.116	...	...	...
280	275	280	275	274	277	274	277	275	280	278	276.6
74	74	74	75	75	76	76	76	76	...	...	74.7
86	86	90	90	94	94	94	96	96	96	96	88.8
102	101	101	104	104	105	105	105	105	105	107	101.6
680	626	671	644	641	680	644	662	626	635	630	627
...	...	...	...	...	...	...	...	...	...	...	...
+1.0	+1.0	+1.0	+1.0	+1.0	+1.0	+1.0	+1.0	+1.0	+1.0	+1.0	+1.0
+.32	+.33	+.38	+.45	+.47	+.48	+.49	+.38	+.37	+.37	+.38	+.388
—.56	—.58	—.56	—.53	—.53	—.54	—.52	—.48	—.47	—.48	—.47	—.526
11.2	...	10.5	...	10.6	...	10.9	...	10.3	...	11.7	10.7
7.3	...	8.5	...	8.6	...	7.9	...	8.2	...	7.7	8.01
·016	...	0.0	...	0.0	...	0.0	...	0.0	...	Trace.	.010
1500	...	1500	...	1500	...	1500	...	1500	...	1479	...
...	...	...	...	...	...	...	...	...	...	...	11829
13915	...	13370	...	13571	...	13960	...	13427	...	13536	...
...	...	...	...	...	...	...	...	...	...	...	108963

Barometer, 29.31.
Weather, partly cloudy and warm, with fresh breeze.
Smoke, light brown to medium, with puffs of black when firing.

TEST No. 3, CLOSED FIRE ROOM,

July 27, 1904.	A. M.					
	9·00	9·30	10·00	10·30	11·00	11·30
Steam pressure, gauge, pounds	280	280	279	278	278	276
Water in gauge glass, inches	1¾	...	3¼	...	4¼	...
Calorimeter, T_1, upper thermometer	403	409	408	408	409	409
T_2, lower thermometer	312	314	313	313	314	314
Q, water in steam, per cent	...	...	.175	...	.117	...
Gauge pressure at reading, inches	280	279	279	277	278	276
Temperature of feed water, degrees, F.	75	75	76	76	76	76
outside air, degrees, F.	89	91	92	92	94	96
fire room, degrees, F.	99	100	102	103	103	103
gases at base of stack, degrees, F.	536	554	700	734	752	737
Draft pressure, inches water; ash pit	+1.42	+1.45	+1.45	+1.46	+1.43	+1.42
fire room	+1.5	+1.5	+1.5	+1.5	+1.5	+1.5
furnace	+.32	+.35	+.38	+.38	+.34	+.33
base of stack	−.52	−.53	−.53	−.54	−.53	−.53
Flue gases, CO_2, per cent	...	...	10.2	...	13.2	...
O, per cent	...	...	8.8	...	5.8	...
CO, per cent	...	...	0.0	...	Trace.	...
Coal per hour, pounds	...	...	1650	...	1500	...
total, pounds	...	...	...	...	...	...
Feed water per hour, pounds	...	...	14830	...	13800	...
total, pounds	...	...	...	...	...	...

Fires judged 6 inches thick at start, 8 inches at end, including 2 inches ash.
Coal, Pocahontas, run of mine, screened.
Refuse, 3.20 per cent. Moisture in coal, 2.8 per cent.
Water ¼ inch higher at end. Total water = 116,446 − 65 = 116,381.

TEST No. 4, CLOSED FIRE ROOM,

July 28, 1904.	A. M.					
	9·00	9·30	10·00	10·30	11·00	11·30
Steam pressure gauge, pounds	275	277	280	274	275	280
Water in gauge glass, inches	3¼	...	5	...	4¼	...
Calorimeter, T_1, upper thermometer	409	409	408	408	408	408
T_2, lower thermometer	313	312	312	312	312	312
Q, water in steam, per cent	...	...	.234	...	.233	...
Gauge pressure at reading, inches	275	278	280	275	275	279
Temperature of feed water, degrees, F.	76	76	76	76	76	76
outside air, degrees, F.	79	80	84	84	86	80
fire room, degrees, F.	96	96	90	87	89	89
gases at base of stack, degrees, F.	590	644	968	761	671	1112
Draft pressure, inches water; ash pit	+1.99	+1.99	+1.99	+1.99	+2.	+2.
fire room	+2.	+2.	+2.	+2.	+2.	+2.
furnace	+.84	+.98	+1.2	+1.05	+1.31	+1.22
base of stack	−.54	−.53	−.53	−.52	−.5	−.48
Flue gases, CO_2, per cent	...	...	12.4	...	11.1	...
O, per cent	...	...	6.6	...	7.6	...
CO, per cent	...	...	Trace.	...	0.0	...
Coal per hour, pounds	...	...	1800	...	1875	...
total, pounds	...	...	...	...	...	...
Feed water per hour, pounds	..	...	15120	...	15679	...
total, pounds	...	...	...	...	...	...

Fire judged 6 inches at start, 8 inches at end, including 2 inches ash.
Coal, Pocahontas, run of mine, screened.
Refuse, 3.15 per cent. Moisture, 3 per cent.

1½ INCHES AIR PRESSURE.

	P. M.										Aver-age.
12·00	12·30	1·00	1·30	2·00	2·30	3·00	3·30	4·00	4·30	5·00	
279	277	280	278	277	274	275	277	275	280	277	277.6
4½	...	5	...	6½	...	4	...	4½	...	2½	...
409	408	410	409	407	405	406	407	408	409	408	407
314	314	314	314	314	313	313	313	312	313	312	313
.117	...	.117	...	.117	...	.174	...	.233	...	...	...
278	276	281	277	275	273	274	276	275	279	265	276
76	76	76	77	77	77	77	77	77	77	77	76.4
96	97	99	99	99	99	98	90	90	90	90	94
105	107	107	107	108	108	105	102	101	103	100	104
724	716	662	671	680	698	752	770	698	671	680	690
+1.43	+1.43	+1.41	+1.42	+1.43	+1.42	+1.42	+1.41	+1.40	+1.45	+1.45	+1.43
+1.5	+1.5	+1.5	+1.5	+1.5	+1.5	+1.5	+1.5	+1.5	+1.5	+1.5	+1.5
+.35	+.41	+.50	+.63	+.78	+.85	+.92	+.93	+.96	+1.	+1.01	+.614
−.57	−.51	−.49	−.50	−.50	−.53	−.55	−.51	−.50	−.49	−.47	−.52
10.8	...	10.6	...	11.5	...	10.3	...	11.1	...	10.5	11.02
8.3	...	8.	...	7.4	...	8.6	...	7.8	...	8.5	7.9
0.0	...	0.2	...	Trace.	...	0.0	...	0.0	...	0.0	.025
1500	...	1650	...	1800	...	1800	...	1650	...	1755	...
...	...	...	...	...	...	...	...	...	...	...	13305
14535	...	14672	...	13902	...	15621	...	14040	...	15046	...
...	...	...	...	...	...	...	...	...	...	...	116446

Barometer, 29.25.
Weather, partly cloudy; warm with strong breeze; thunderstorm in afternoon.
Smoke, light to medium, with puffs of black when firing, quickly disappearing.

2 INCHES AIR PRESSURE.

	P. M.										Aver-age.
12·00	12·30	1·00	...	...	...	...	...	...	...	...	
273	277	272	...	...	...	...	...	...	...	...	276
5½	...	3½	...	...	...	...	...	...	...	...	...
409	408	408	...	...	...	...	...	...	...	...	408.3
312	312	312	...	...	...	...	...	...	...	...	312
.233	...	.233	...	...	...	...	...	...	...	...	...
276	277	270	...	...	...	...	...	...	...	...	276
76	76	76	...	...	...	...	...	...	...	...	76
80	80	80	...	...	...	...	...	...	...	...	81.4
92	92	94	...	...	...	...	...	...	...	...	91.7
698	626	689	...	...	...	...	...	...	...	...	751
+1.97	+1.96	+1.96	...	...	...	...	...	...	...	...	+1.98
+2.	+2.	+2.	...	...	...	...	...	...	...	...	+2.
+1.3	+1.34	+1.3	...	...	...	...	...	...	...	...	+1.17
−.55	−.49	−.52	...	...	...	...	...	...	...	...	−.52
10.8	...	10.	...	...	...	...	...	...	...	...	11.07
8.4	...	9.1	...	...	...	...	...	...	...	...	7.92
0.0	...	0.0	...	...	...	...	...	...	...	...	0.0
1875	...	1855	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	7405
15870	...	15954	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	62623

Barometer, 29.19.
Weather, cloudy and warm, with showers.
Smoke, light, with puffs of black when firing.

TEST No. 5, CLOSED FIRE ROOM, 2.66 INCHES AIR PRESSURE.

July 28, 1904.	P. M.									Average.
	1'00	1'30	2'00	2'30	3'00	3'30	4'00	4'30	5'00	
Steam pressure gauge, pounds	272	273	276	276	273	279	272	274	270	273
Water in gauge glass, inches	3¼	...	5	...	5¼	...	4¼	...	3¼	¼*
Calorimeter, T_1, upper thermometer	408	405	409	408	408	408	408	407	408	407.6
T_2, lower thermometer	312	311	312	311	311	311	311	311	311	311.2
Q, water in steam, per cent	...	...	.233	...	.292	...	.292	...	.291	...
Gauge pressure at reading, inches	270	272	276	277	272	280	272	275	268	272.4
Temperature of feed water, degrees, F	76	76	76	76	76	76	76	76	76	76
outside air, degrees, F	78	76	76	76	76	76	76	78	78	76.6
fire room, degrees, F	94	93	93	92	91	91	91	92	91	92
gases at base of stack, degrees, F	689	680	644	653	644	635	626	608	612	644
Draft pressure, inches water; ash pit	+2.70	+2.64	+2.65	+2.66	+2.66	+2.67	+2.64	+2.65	+2.67	+2.66
fire room	+2.75	+2.70	+2.70	+2.70	+2.70	+2.70	+2.70	+2.70	+2.70	+2.70
furnace	+1.61	+1.93	+1.85	+1.90	+1.81	+1.67	+1.75	+1.64	+1.69	+1.76
base of stack	−.53	−.46	−.48	−.44	−.51	−.54	−.52	−.51	−.52	−.501
Flue gases, CO_2, per cent	...	...	10.1	...	10.8	...	10.	...	10.1	10.25
O, per cent	...	...	8.8	...	8.1	...	8.9	...	8.9	8.67
CO, per cent	...	...	0.	...	0.2	...	0.	...	0.	0.05
Coal per hour, pounds	...	...	2100	...	2100	...	2175	...	2141	...
total, pounds	...	...	...	...	...	...	...	...	...	8516
Feed water per hour, pounds	...	...	17110	...	16327	...	18303	...	18389	...
total, pounds	...	...	...	...	...	...	...	...	...	70129

Fires judged same at end as at start.
Coal, Pocahontas, run of mine, screened.
Refuse, 3.15 per cent. Moisture, 3 per cent.
Total water, corrected for water level = 70,129 − 31 = 70,098 pounds.

* Difference in level.

Weather, cloudy and warm with showers.
Barometer, 29.19.
Smoke, medium to heavy, black puffs when firing.

No. of Test	1	2	3	4	5
1. Date of test	1904, July 25.	1904, July 26.	1904, July 27.	1904, July 28.	1904, July 28.
2. Duration of test, hours	8	8	8	4	4
3. Kind of fuel	Pocahontas run of mine, screened.				
4. Kind of start	Alt.	Alt.	Alt.	Alt.	Alt.
5. State of weather	*	†	‡	§	‖
Average Pressures.					
6. Barometer, inches	29 34	29.31	29.25	29.19	29.19
7. Steam pressure by gauge, pounds	275.7	276	277.6	276	273
8. Force of draft at base of pipe, ins. of water	—.526	—.526	—.52	—.52	—.501
9. Force of draft in furnace, ins. of water	—.183	+.388	+.614	+1.17	+1.76
10. Force of draft in ash pit, ins. of water	+.5	+1	+1.43	+1.98	+2.66
11. Revolutions of blower	546	546	546	546	546
Average Temperatures.					
12. External air, degrees F	78.5	88.8	94	81.4	76.6
13. Fire room, degrees F	93.4	101.6	104	91.7	92
14. Steam, degrees F	407	407.4	407	408.3	407.6
17. Feed water entering boiler, degrees F	75	74.7	76 4	76	76
18. Air entering ash pit, degrees F	93.4	101.6	104	91.7	92
19. Escaping gases from boiler, degrees F	533	627	690	751	644
Fuel.					
21. Kind of	Pocahontas run of mine, screened.				
23. Weight of coal as fired, pounds**	8,061	11,829	13,305	7,405	8,516
24. Moisture in coal, per cent	2.7	2.37	2.8	3	3
25. Weight of dry coal consumed, pounds	7,843.4	11,549	12,933	7,183	8,261
26. Weight of ash and refuse, pounds	354	596	513	233	268
27. Weight of combustible consumed, pounds	7,488.72	10,953	12,420	6,950	7,993
28. Per cent. of refuse in dry coal	4.4	4.14	3.2	3.15	3.15
Fuel per Hour.					
29. Coal consumed, pounds	1,007.6	1,478.6	1,663	1,851.25	2,129
30. Dry coal consumed, pounds	980.4	1,443.6	1,616.6	1,796	2,065
31. Combustible consumed, pounds	936.09	1,369	1,552.5	1,737.5	1,998
32. Coal consumed per sq. ft. G. S., pounds	22.4	32.69	36.77	40.93	47.07
33. Dry coal consumed per sq. ft. G. S., lbs.	21.8	31.92	35.74	39.71	45.66
34. Combustible consumed per sq. ft. G. S., lbs.	20.8	30.27	34.32	38.41	44.17
35. Coal per sq. ft. H. S., pounds	.54	.798	.898	.999	1.14
36. Dry coal per sq. ft. H. S., pounds	.528	.779	.872	.969	1.11
37. Combustibles per sq. ft. H. S., pounds	.510	.739	.838	.937	1.07
Quality of Steam.					
38. Per cent. of moisture in steam	.09	.14	.17	.23	.28
40. Quality of steam (dry steam = 100)	.9991	.9986	.9983	.9977	.9972
Water.					
41. Total weight of water fed to boiler, lbs.	77,140	108,963	116,381	62,623	70,098
42. Water actually evaporated, corrected for quality of steam (40 by 41), pounds	77,071	108,810	116,183	62,479	69,902
43. Factor of evaporation	1.2064	1.2067	1.2052	1.2056	1.205
44. Equivalent water evaporated into dry steam from and at 212° (42 by 43) lbs.	92,978	131,301	140,024	75,325	84,232
Water per Hour.					
45. Water evaporated, corrected for quality of steam, pounds	9,634	13,601	14,523	15,619	17,475
46. Equivalent evaporation from and at 212°	11,622	16,412	17,503	18,831	21,058
47. Equivalent evaporation from and at 212° per sq. ft. G. S., pounds	256.98	362.9	387.02	416.38	465.62
48. Same per sq. ft. of heating surface, lbs.	6.27	8.85	9.44	10.16	11.36
Economic Results.					
49. Water apparently evaporated under actual conditions per pound of coal as fired (41 ÷ 23), pounds	9.56	9.21	8.747	8.456	8.23
50. Apparent equivalent evaporation from and at 212° per pound of coal (including moisture) (44 ÷ 23,) pounds	11.53	11.09	10.524	10.172	9.89
51. Equivalent evaporation from and at 212° per pound of dry coal (44 ÷ 25), pounds	11.85	11.36	10.826	10.486	10.19
52. Equivalent evaporation from and at 212° per pound of combustible (44 ÷ 27), lbs.	12.41	11.98	11.274	10.837	10.53
Remarks and Observations.					
55. Principal data taken every minutes	30	30	30	30	30
58. Kind of firing (spreading, alternate or coking)	Alt.	Alt.	Alt.	Alt.	Alt.
62. Efficiency of firemen; expert, average, poor.	Expert.	Expert.	Expert.	Expert.	Expert.

* Partly cloudy and warm, with light breeze.
† Partly cloudy and warm, with fresh breeze.
‡ Partly cloudy and warm, with strong breeze; thunderstorm in afternoon.
§ Cloudy and warm, with showers.
** Including addition for ash left on grates at end of test.

CONTRACT TRIAL OF TORPEDO BOAT No. 27, THE *BLAKELY.*

On July 21–22, 1904, the *Blakely* successfully underwent the official trials prescribed by the contract and has now been preliminarily accepted by the Government. The delay in these trials was due to defects which developed during earlier trials, June 19, 1902, partially wrecking the port engine and requiring the renewal of the casting for the port H.P. and I.P. cylinders.

As the *Blakely* is similar in all respects to the *DeLong*, built by the same contractors, the description of the latter vessel, JOURNAL, Volume XIV, No. 3, August, 1902, is republished with such changes only as involve names, new data, etc.

The U. S. torpedo boat No. 27, *Blakely*, is one of two boats built by the George Lawley and Son Corporation, of South Boston, Mass., on the same plans and specifications, the general plans and specifications being furnished by the Department. These boats were two of a number of boats authorized by Congress in an act entitled "An act making appropriations for the Naval Service for the fiscal year ending June 30, 1899, and for other purposes." This act was approved May 4, 1898, and authorized the construction of twelve torpedo boats of about 150 tons displacement, to have the highest practicable speed.

The contract was signed September 27, 1898, the price being $159,400, and the time allowed for completion, one year. On March 20, 1900, the Department granted an extension of time for completion of twelve months to the builders of torpedo-boat destroyers and torpedo boats authorized by the act of May 4, 1898.

The work on these boats was greatly delayed because of the inability of the contractors to obtain material.

On April 17, 1901, the Department granted a further extension of time of ten months for the completion of torpedo boats *Blakely*

and *DeLong*, and, later, a further extension for the *Blakely* to include date of delivery to the Government.

The price stated above does not include ordnance, ordnance outfit, air compressor and plant, compasses and other equipment, fittings and stores which are supplied by the Government.

The speed guaranteed in the original contract was 26 knots an hour, to be maintained for two consecutive hours over a course not less than 20 nautical miles in length, the vessel, on speed trial, to carry 9 tons of ordnance, 8 tons of equipment and 10 tons of coal, or equivalent weights similarly placed, in addition to complete machinery with spare parts and engineers' stores.

It was provided in the contract that a penalty at the rate of $12,000 per knot should be inflicted in case the speed fell below 26 knots, and if a speed of 25 knots could not be reached on trial the vessel was to be rejected. The original speed requirements were modified by the Navy Department on February 26, 1902. These modifications reduced the speed to 25 knots per hour for the mean of two runs in opposite directions over a measured nautical mile, and to 24 knots to be maintained for one hour, the weighting of the boat to be the same as originally required.

The total weight of machinery and boilers, including auxiliaries—distilling plant, steam-heating plant, water in boilers, condensers, pipes and feed tanks, also stores, tools and spare parts—was limited to eighty tons, and a penalty was fixed for overweight at the rate of $200 per ton, with the further provision that if the overweight exceeded 5 per cent. an additional penalty of $1,000 was to be inflicted.

HULL.

Length between perpendiculars, feet	175
over all, feet	175
Beam, extreme, feet and inches	17–7
L.W.L., feet and inches	16–10½
Ratio of length to beam	9.95 to 1
Mean draught on trial, feet and inches	5–9½
Displacement on trial, tons	192.5
per inch at L.W.L., tons	5.4
Area of L.W.L. plane, 165 tons, square feet	2,230
Center of L.W.L plane aft of midship section, feet	11.1

Center of buoyancy above keel, feet	3
aft of midship section, feet	0.1
Area of immersed midship section, square feet	57.5
Transverse metacenter above center of buoyancy, inches	7.05
Longitudinal metacenter above center of buoyancy, feet	677.5
Number of frames	115

The hull is constructed of mild steel of domestic manufacture, with frames spaced 18 inches apart, except where intermediate frames are placed. The outer keel plate from frame 27 to frame 96 is 10-pound plate; forward and aft of these frames it is 7½-pound plate. The shell plating abreast boiler and machinery spaces (frames 31 to 82) is 7-pound plate; forward and aft of these spaces it is 5 and 6-pound plate.

The ship is divided into eleven principal compartments by ten 'thwartship, watertight steel bulkheads extending to the sides of the vessel and to the deck. These compartments are, consecutively, the fore peak, windlass room, officers' quarters, petty officers' quarters, forward boiler room, forward engine room, after engine room, after boiler room, galley and crew's mess room, crew's quarters and tiller room. Store rooms and magazines are provided below the floors of the living spaces and below the windlass room.

The boat is fitted with a ½-inch nickel-steel conning tower forward and a 7-pound mild-steel plate conning tower aft. In the forward conning tower the steam and hand-steering gear is located; also revolution indicator and voice pipe to forward engine room. This conning tower also contains entrance to officers' quarters, and the searchlight is placed on top of it.

The after conning tower contains hand-steering gear, voice pipe to after engine room and entrance to crew's quarters and mess room.

Besides the voice pipes in conning towers, the various compartments of the engineering department are similarly connected, as follows: The forward engine room is connected with the forward boiler room, and the after engine room is connected with the after boiler room.

The boats carried are as follows: One 18-foot dinghy, one 14-foot dinghy, one 17-foot canvas folding boat.

Coal Bunkers.—There are eight coal bunkers, with a capacity of about 70 tons, at 43 cubic feet to the ton. In the bottoms of the two 'midship coal bunkers, alongside the engine rooms, the eight reserve feed tanks are placed. These tanks hold about 1,700 gallons of water.

The coal bunkers in the boiler rooms are fitted with watertight sliding doors, and the engine-room coal bunkers communicate with those forward and aft by means of openings provided with watertight hinged doors.

Escape rungs are fitted in each coal bunker leading to the bunker openings in the deck.

Drainage.—The drainage systems are as follows:

(1) A 5-inch drain pipe connected to the after circulating pump, having suctions and valves in after engine room and after boiler room; a 5-inch drain pipe connected to the forward circulating pump, having suctions and valves in the forward engine room and forward boiler room.

(2) A 2½-inch drain pipe connected to both fire and bilge pump and to the auxiliary feed pump, from which suctions lead to each compartment except forward collision compartment and tiller compartment; these two compartments are sluiced into compartments next to them.

(3) A system of steam ejectors, with separate connections to each of the compartments in the boiler and machinery spaces and also in petty officers' and crew's quarters spaces.

A series of limber holes in the vertical keel allows water to drain from side to side.

ARMAMENT.

The battery consists of three long 1-pounder rapid-fire guns, mounted on deck, one on each side, immediately aft of forward conning tower, and one on the center line of ship aft of after conning tower. There are three tubes for torpedoes situated on deck, one on each side, just forward of the center, and one on the stern.

The original design called for three 3-pounder, quick-firing, semi-automatic guns, located as above. The change in battery requirements was made at same time change in speed require-

ment was made, the Department still insisting, however, that contractors must run the official trial with weights on board equal to those required by original armament.

The Department decided at the same time that the two spare torpedoes which were originally specified would not be required, though their equivalent weight must be carried on the official trial.

MAIN ENGINES.

There are two vertical, inverted, direct-acting, four-cylinder, triple-expansion engines, placed in separate watertight compartments, the starboard engine being forward of the port, each engine having the high-pressure cylinder forward.

The high and intermediate-pressure cylinders are in one casting, and, together with the two low-pressure cylinders, are supported by eight forged-steel columns.

The main valves are of the single-ported piston type, there being one for each cylinder. The I.P. and both L.P. valves are provided with balance pistons, the cylinders for which form part of the upper covers of the valve chest. The H.P. and I.P. valves are plug valves, and the L.P. valves have spring rings.

Live steam connection is made with the I.P. and L.P. receivers. The auxiliary exhaust has a connection with the condenser, the L.P. receivers and the atmosphere.

The valve gear is of the Stephenson link type, with double-bar links and crossed rods. Provision is made on each cylinder for an adjustment of cut-off by means of a sliding block in reverse-shaft arm, which block can be moved by hand-screw gear.

The main pistons are steel forgings, dished, and each is fitted with two packing rings $\frac{5}{8}$ inch wide and $\frac{7}{16}$ inch thick. The piston rods and connecting rods are of forged steel. The crossheads are of forged steel, in one piece with piston rods, the ahead sides of sliding faces being fitted with white metal. The go-ahead crosshead guide is of cast iron, bolted to forged-steel strongbacks, which are in turn bolted to the engine columns. The guide is cast hollow, for the circulation of water.

The backing guides are of composition and bolted to the face of the go-ahead guide.

The eccentrics are forged on the shaft. The eccentric straps are of composition, faced with white metal, and the eccentric rods are of forged steel.

The valve stems and valve-stem crossheads are of steel, forged in one piece, and take hold of the link blocks directly.

Each engine-bed plate consists of five cast-steel bearers bolted to two forged-steel plates running fore-and-aft, which, in turn, are bolted down and held by body-bound bolts to fore-and-aft engine keelsons.

The reversing gear consists of a steam cylinder connecting directly to an arm fixed on the reversing shaft. The valve of the steam reversing cylinder is of the common slide-valve type worked by a system of differential levers, the primary motion being derived from the hand lever at the working platform, and the secondary motion from an eccentric on the reverse shaft.

The end of the reversing shaft is fitted to receive a hand lever for reversing engines by hand. The turning gear consists of a worm and wormwheel attached to coupling on after end of engine and is operated by means of a ratchet lever.

Each engine is fitted with a double-poppet throttle valve bolted to flange on connecting pipe between top and bottom of H.P. steam chest. Each throttle lever is provided with a latch and a worm gear for fine adjustment.

MAIN ENGINE DATA.

Cylinders, number for each engine	4
H.P., diameter, inches	14
I.P., diameter, inches	22
L.P. (2), diameter, inches	25½
Stroke, inches	18
Valves, H.P. (1 for each cylinder), diameter, top, inches	7⅛
bottom, inches	7½
I.P. (1 for each cylinder), diameter, top, inches	14⅛
bottom, inches	14½
L.P. (1 for each cylinder), diameter, top, inches	16⅛
bottom, inches	16½
Side of valve on which steam is taken :	
H.P.	Outside.
I.P.	Inside.
L.P. (both)	Outside.
Balance pistons, H.P., diameter	None.
I.P., diameter, inches	4½

Balance pistons, L.P. (each), diameter, inches	4¼
Valve stems, H.P., diameter, inches	1⅝
I.P., diameter, inches	1⅝
L.P., diameter (each), inches	1⅝
Main steam pipe, diameter, inches	5½
exhaust pipes (2), diameter, inches	10
Piston rods, diameter, inches	3
of axial hole, H.P. and I.P., inches	1 1/16
L.P., inches	2
Connecting rods, center to center, inches	40
section at upper end, H.P. and I.P. (each), inches	1¼ × 3¼
L.P. (each), inches	1⅛ × 3
section at lower end, H.P. and I.P. (each), inches	1 × 5
L.P. (each), inches	⅞ × 4¼
Crank pins, H.P. and I.P., inches	6¼ × 9
L.P. (each), inches	6¼ × 7
Crank-pin bolts (2), diameter, inches	1⅞
Crosshead pins, H.P. and I.P., inches	3⅜ × 5¼
L.P. (each), inches	3⅜ × 4¼
axial hole, diameter, inches	1¼
Crossheads, wearing surface, H.P. and I.P., ahead, inches	13¼ × 7½
L.P., ahead, inches	11¼ × 6½
H.P. and I.P., backing (2), each, ins.	13¼ × 2¼
L.P., backing (2), each, inches	11¼ × 2¼

Shafting and Bearings.—The crank, line and propeller shafting is hollow and of forged steel. The crank shaft of each engine is in one forging, the eccentrics being part of shaft. The cranks of the H.P. and I.P. cylinders are opposite each other, as are also the 1st and 2d L.P. cranks, the first two being at right angles with the last two. The sequence of the cranks for ahead motion is H.P., 1st L.P., I.P. and 2d L.P. The line shafts are supported by spring bearings and the propeller shafting by struts, the latter being encased in brass sleeves at bearings. The stern-tube shafting is also encased in a brass sleeve where it passes through stern tube.

Each thrust bearing is of cast steel, made in halves, and lined with white metal. The thrust is taken by two 2-inch steel bolts screwed into the aftermost of the engine bearers, and secured to the thrust bearing by means of nuts on either side of the bosses provided for that purpose on the bearing.

Main Condensers.—There are two main condensers, one for each engine. The shells are of Muntz metal plate stiffened with

tee and angle rings. The water chests are of copper and tube sheets are of Muntz metal. The tubes are of Muntz metal, tinned inside and out, and are screwed into the tube sheet at one end, the other end being provided with screw glands. The circulating water passes through the tubes. A baffle plate with holes is fitted to direct the steam over all the tubes. A direct-connected, centrifugal pump furnishes circulating water when the boat is not under way. When running, water is forced through the condensers by the speed of the boat, scoops with strainers being fitted over the injection openings.

MAIN CONDENSER DATA.

Diameter, feet and inches	3–1
Thickness	No. 10 B.W.G.
Number of tubes	1,261
Length between tube sheets, feet and inches	6–2
Diameter of tubes, inch	$\frac{5}{8}$
Thickness of tubes	No. 18 B.W.G.
Cooling surface, each condenser, square feet	1,241
total, square feet	2,482
Ratio total cooling to total heating surface	1 to 3.05
Diameter of circulating-pump runner, inches	18
Width of circulating-pump runner, inches	$1\frac{1}{4}$
Diameter of inlet nozzle of circulating pump (2), each, inches	7
outlet nozzle of circulating pump, inches	9
Size of circulating engine, single cylinder, slide valve, stroke, ins	4×3

Main Air Pumps.—For each engine there is a double-acting, center-suction air pump of the Bailey type, worked through a rocker by an eccentric on main shaft. The pump valves are made of manganese-bronze.

Main Circulating Pumps.—For each condenser there is a centrifugal, double-inlet circulating pump which is arranged to draw from the sea, its engine room and adjacent fireroom bilge, and to discharge into the condenser. It is driven by an independent, vertical, single-cylinder engine. Each pump is capable of discharging 750 gallons of water per minute from the bilge.

Screw Propellers.—The propellers are of manganese-bronze, tinned, each having four blades. They are true screws, the starboard one being left-handed and the port one right-handed. Each propeller is secured on its shaft by a single key and a composition cap nut screwed on and locked in place.

Number of blades	4
Diameter, feet and inches	5–6
Length of hub, inches	12¼
Mean pitch, feet and inches	9–6.72
Helicoidal area, square feet	10.80
Projected area, square feet	7.33
Disc area, square feet	23.76
Ratio of diameter to mean pitch	1 to 1.74
Weight, complete, pounds	775

BOILERS.

There are three water-tube boilers of the Normand type, two of which are located in the watertight compartment immediately forward of the engine rooms and the third in the watertight compartment immediately abaft the engine rooms.

There is one furnace with two doors under each boiler. These furnaces are lined with firebrick. The grate bars are of mild steel. The casing is of thin sheet iron, lined with magnesia and asbestos, with one uptake and smoke pipe for each boiler.

Each boiler is placed in saddles built in the boat under the bottom drums. Each boiler has one twin 3½-inch spring safety valve placed on the stop-valve nozzle.

The main feed water is discharged through brass pipes connected with a Thornycroft feed-water regulator, and the auxiliary feed is discharged through a separate pipe, both leading into the down-take pipes at the front of the boiler.

BOILER DATA.

Steam pressure designed, pounds	250
Number of boilers	3
Width over casing, feet and inches	10–8
Height, feet and inches	10–8
Steam drum, length, feet and inches	10–6
diameter, inside, inches	32
thickness, inch	7/16
where drilled for tubes, inch	⅞
Water drums, number for each boiler	2
diameter inside, inches	16
thickness, inch	⅝
Furnaces, number each boiler	1
width of grate, feet and inches	6–5
length of grate, feet and inches	7–9⅜
doors, each furnace	2
Tubes, diameter, inches (O.D.)	1⅛

Tubes, number in each boiler	1,244
thickness	No. 11 B.W.G.
Grate surface, three boilers, square feet	150
Heating surface, three boilers, square feet	7,575
Ratio grate surface to heating surface	1 to 50.5
Smoke pipes, number	3
dimensions, inches	24 × 36
area of each, square feet	5.14
height above grates, feet and inches	20–2
Ratio of smoke-pipe area to grate area	1 to 9.73

OTHER MACHINERY.

Forced Draft.—The closed-fireroom system of forced draft is used, air being supplied by three blowers located, two in the forward fireroom and one in the after fireroom. These blowers are placed with their shafts vertical immediately below the ventilator through which the air is taken.

Each fan is driven by a direct-connected double engine having piston valves and cranks at 180 degrees. Cylinders, diameter, 4 inches; stroke, 3 inches. Fan, diameter, 42 inches; width at rim, 12 inches. Area of induction nozzle, 452 square inches; area of eduction nozzle, 1,582 square inches.

Ash Ejectors.—There is one Davidson hydraulic ash ejector in each fireroom.

Feed Pumps.—There are two main and one auxiliary feed pumps of the Davidson type, all of the same size, each pump having one 10-inch by 12-inch steam cylinder and 6-inch by 12-inch water cylinder, with a capacity of 147 gallons at 100 feet piston speed.

The main feed pumps are located, one in the forward fireroom and one in the after engine room, and draw from the hot wells, communicating pipe of reserve feed tanks and adjacent air-pump channel way, and deliver to the boilers and reserve feed tanks.

The auxiliary feed pump is located in the forward engine room. This pump has a suction from the forward hot well, the communicating pipe of reserve feed tanks, the forward air-pump channel way, the sea and the drainage system, and discharges into the boilers, fire main and overboard. The discharge pipes from the main and auxiliary feed pumps to the boilers are independent pipes and check valves.

Fire and Bilge Pumps.—In the after engine room there is a vertical Davidson fire and bilge pump, with 6-inch by 12-inch steam cylinder and 6-inch by 12-inch water cylinder, which draws from the sea, bilge and drainage system and delivers into the fire main, ash-ejector main and overboard. It has a capacity of 147 gallons at 100 feet piston speed.

Water-Service and Distiller Circulating Pump.—In the after fireroom there is a vertical Davidson pump which draws from the sea and delivers into the water-service pipes and the distiller circulating pipes. It has a capacity of 50 gallons at 100 feet piston speed. The steam cylinder is 3½ inches by 4 inches, and the water cylinder is 3½ inches by 4 inches.

Feed Tanks.—There is a feed tank of 64 gallons capacity in each engine room. This tank is fitted with a compartment filled with a filtering material through which the water from the air pump is delivered to the feed-pump suctions. Each tank has three manhole plates near the bottom, and also a cover which is removable. Each is fitted with a thermometer, water-gauge glass, and a copper ball float so arranged that it will operate a valve in the steam pipe to the adjacent main feed pump, thus maintaining a constant water level in tank.

Each tank has the following pipe connections: A discharge pipe from the air pump. An overflow gooseneck pipe leading on the inside from near the bottom of tank, with its outside end above top of tank, so arranged that any water passing through it into the bilge may be seen; this provides an overflow without a cumbersome relief valve and still prevents the discharge of vapors into the engine room. A suction pipe to feed pumps. Discharge pipes from traps. A vapor pipe opening to escape pipes.

Steam Traps.—The separators in the main and branch steam piping are all connected with automatic traps which discharge into the feed tanks.

Distilling Apparatus.—In the after fireroom there are two Davidson evaporators and one Davidson distiller, the specifications requiring of the evaporators a combined capacity of 2,000 gallons of water at 90 degrees Fahrenheit in 24 hours. The

water-service pump is also used for the distiller circulating pump. There is one Davidson evaporator feed pump which may also be used as a brine pump; size of cylinders, 3 inches by 1¾ inches by 4 inches.

Steering Gear.—The steering engine is located in the forward conning tower and has two cylinders 3¾-inch diameter by 4-inch stroke, with cranks at 90 degrees. This engine operates, through a worm and a system of gearing, a rack, the ends of which are connected to the quadrant on tiller by wire ropes. The valve controlling this engine is operated by the steering wheel, which wheel may be used for direct hand steering by throwing out a clutch. With the steam gear the helm can be put from hard over to hard over in eleven seconds.

Steam Windlass.—There is a steam windlass built by the Hyde Windlass Company, of Bath, Maine, situated on a platform in the forward end of the ship. It has a double engine, with cylinders 3¼ inches by 4 inches and cranks at 90 degrees. The windlass is provided with two drums, each capable of holding 75 fathoms of $\frac{9}{16}$-inch wire cable, and is connected with a capstan situated on deck.

Air Compressor.—There is one air compressor made by E. W. Bliss, Type II, for torpedoes, located in the after engine room.

Telegraphs and Revolution Indicators.—There is a Corey mechanical telegraph in each engine room connected to transmitters in each conning tower.

Mechanical tell-tales are fitted in each conning tower to show the direction of the revolutions and relative speeds of the main engines. In each engine room there is also a mechanical indicator to show the relative speeds and direction of the revolutions of the main engines. The mechanical tell-tales are operated by a separate line of shafting from each main engine, which extends throughout the boat from the forward to the after conning tower.

Each engine-room indicator has two hands revolving in the same direction, a red one which turns with the port engine and a green one which turns with the starboard engine. These hands can be shifted on their spindles so as to be brought into coincidence when desired.

Revolution Counters.—In each engine room there is a positive-

motion revolution counter which is operated from an independent shaft engaging with the main crank shaft.

Each engine room is connected with the adjacent fireroom, and both engine rooms are connected together by a mechanical repeating telegraph for transmitting engine and fireroom signals.

ELECTRIC-LIGHT PLANT.

Current for the lighting system is supplied by a generating set made by the General Electric Company, consisting of a 2½-kilowatt dynamo of multipolar type, with a capacity of 31 ampères at 80 volts, located in the forward engine room.

The dynamo is direct-connected to a 3-inch by 3-inch engine, with piston valve and flywheel governor, designed to run at 800 revolutions per minute with full load, both being mounted on one base.

The switchboard, containing instruments and switches controlling the different circuits, is located immediately over the generator on bulkhead between engine rooms. A searchlight is located on top of the forward conning tower. Portable lights with flexible connections are provided for magazines and storerooms, in addition to fixed lights in living and machinery spaces. Electric connections are furnished for running and signal lights, these also being arranged to burn oil.

TRIALS—NOTES.

The progressive speed trials for the standardization of propellers took place over the measured mile at Newport, R. I., July 21, 1904. The weather conditions were good; sea smooth; light breeze from W.N.W.

The one-hour's speed trial and endurance run was made July 22, 1904, starting from the vicinity of Gould's Island, out to sea, with a long turn, and then finishing the run at about the place of starting.

When making the standardization runs the various speeds were obtained by a fixed pressure at the H.P. chest, the revolutions corresponding to various speeds having been determined on preliminary runs.

The results of the standardization runs with and against the

tide having been plotted as separate curves, the curve of true speed was constructed, from which was taken the mean revolutions of both engines (333.5) required to give a true speed of 24 knots. The slip of propellers was calculated for a mean pitch of 114.72 inches.

As shown by the tables, a mean speed of 25.5773 knots was made on the fourth double run of the standardization trials, while the speed corresponding to the mean revolutions of both engines for the one-hour trial was 24.15 knots.

The fuel used on these trials was picked Pocahontas coal of good quality.

WEIGHTS OF *BLAKELY*.

Group.		*Pounds.*
1.	Main engine cylinders	13,611
2.	Shafting	15,747
3.	Main engine framing and bearings	10,106
4.	Reciprocating parts main engines	3,635.2
5.	Main engine valve gear	3,499.9
6.	Main condensers	7,721
7.	Main air and circulating pumps	3,265
8.	Propellers	1,547
9.	Boilers	49,003
10.	Boiler fittings	20,443.8
11.	Smoke pipes	1,684
12.	Steam and exhaust pipes and valves	9,232
13.	Suction and discharge pipes and valves	8,613
14.	Lagging and clothing	3,445
15.	Flooring, gratings, etc	2,996
16.	Auxiliaries	6,649
17.	Fittings and gear	4,264
18.	Water	16,600
19.	Stores, tools, spare parts, etc	3,851.7
20.	Distilling and heating plants	4,829
21.	Miscellaneous machinery, etc	7,412

TABLES OF OFFICIAL STANDARDIZATION TRIAL.

ON DECK DATA.—OFFICIAL STANDARDIZATION TRIAL OF TORPEDO BOAT NO. 27, "BLAKELY", NEWPORT, R. I., JULY 21, 1904.

Run No. and direction.	Time on course.	Revolutions on course.		Mean rev's per min.	Speed.
	m. s.	*Stbd.*	*Port.*		*Knots.*
1. North	2 57.5	803	813	273.1	20.2817
2. South	2 55	791.7	801	273	20.5714
3. North	2 39.5	808.3	827	307.6	22.5705
4. South	2 38.5	802.7	819	306.9	22.7129
5. North	2 28.5	830.3	851	339.7	24.2424
6. South	2 27.25	827.8	849	341.6	24.4482
7. North	2 20.5	854.2	865	367.1	25.6228
8. South	2 21	853	868	366.2	25.5319

ENGINE-ROOM DATA.—OFFICIAL STANDARDIZATION TRIAL OF TORPEDO BOAT NO. 27, "BLAKELY", NEWPORT, R. I., JULY 21, 1904.

.....	First double run.		Second double run.		Third double run.		Fourth double run.	
Direction.....	S.	N.	S.	N.	S.	N.	S.	N.
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
Duration.....	2'55	2'57.5	2'38.5	2'39.5	2'27.2	2'28.5	2'21	2'20.5
Mean speed on double run..	20.4265		22.6417		24.3453.		25.5773	
Mean revolutions per minute on double run.....	273.05		307.25		340.65		366.65	
Mean apparent slip of screws, per cent.....	20.315		18.438		24.25		26.046	
Steam pressure in engine rooms:								
Starboard.....	146	145	180	180	225	225	235	240
Port.....	130	131.5	170	172	212	213	235	245
Steam pressure, 1st receiver, pounds, absolute:								
Starboard.....	48	48	61	61	76	77	81	81
Port.....	45	46.5	59	60	75	75.5	80	90
Steam pressure, 2d receiver, pounds, absolute:								
Starboard.....	15	15	16.2	16	20.5	21	22	23
Port.....	13.5	13.5	16	16.5	21	21	24	25
Vacuum:								
Starboard.....	24.75	24.75	24.5	24.5	23.75	23.75	23	23.5
Port.....	25	25	24.5	24.5	23.5	23	22	21.5

ON-DECK DATA.—OFFICIAL ONE-HOUR RUN OF TORPEDO BOAT NO. 27, "BLAKELY", NEWPORT, R. I., JULY 22, 1904.

Time.	Counter.		Revolutions in interval.		Mean revolutions per minute.	
a. m.	*Starboard.*	*Port.*	*Starboard.*	*Port.*	*Starboard.*	*Port.*
9'43	65,870	62,640				
9'48	67,538	64,343	5m. 1,668	5m. 1,703	333.6	340.6
9'53	69,208	66,048	5m. 1,670	5m. 1,705	334	341
9'58	70,871	67,755	5m. 1,663	5m. 1,707	332.6	341.4
10'03	72,532	69,457	5m. 1,661	5m. 1,702	332.2	340.4
10'08	74,190	71,136	5m. 1,658	5m. 1,679	331.6	335.8
10'13	75,847	72,817	5m. 1,657	5m. 1,681	331.4	336.2
10'18	77,489	74,508	5m. 1,642	5m. 1,691	328.4	338.2
10'23	79,159	76,192	5m. 1,670	5m. 1,684	334	336.8
10'28	80,829	77,882	5m. 1,670	5m. 1,710	334	342
10'33	82,511	79,588	5m. 1,682	5m. 1,706	336.4	341.2
10'38	84,200	81,302	5m. 1,689	5m. 1,714	337.8	342.8
10'43	85,905	83,024	5m. 1,705	5m. 1,722	341	344.4
			Below is result for one hour.			
9'43	65,870	62,640	60m. 20,035	60m. 20,384	333.9	339.7
10'43	85,905	83,024				

Mean revolutions per minute of both engines for one hour, 336.8, corresponding to a speed of 24.15 knots.

ENGINE DATA.—OFFICIAL ONE-HOUR TRIAL OF TORPEDO BOAT No. 27, "BLAKELY", NEWPORT, R. I., JULY 22, 1904.

Time, A. M.	Counter.	Revolutions per minute.	Steam pressure above atmosphere.				Vacuum.	Temperature, degrees F.			Air pressure, fire rooms, inches of water.
			Steam pipe, engine room.	H.P. valve chest.	Receivers. First.	Receivers. Second.		Injection.	Discharge.	Feed water.	
					Starboard Engine.						
9·43	65,870	...	263	225	77	20	24.5	70	105	128	1
9·53	69,208	333.8	265	225	77	20.5	24.5	70	105	128	1.25
10·03	72,532	332.4	265	225	77	21	24.5	70	102	128	.9
10·13	75,847	331.5	265	227	77	21	24.5	70	102	130	1
10·23	79,159	331.2	264	230	78	22.5	24.5	70	102	128	.9
10·33	82,511	335.2	264	230	78	22	24.5	70	102	130	2.3
10·43	85,905	339.4	263	225	73	20	24.5	70	102	128	2.3
Mean.	$\frac{20,035}{60}$	= 333.9	264	226.7	76.1	21	24.5	70	103	128.5	1.37
					Port Engine.						
9·43	62,640	...	260	209	74	19	24	70	110	117	1.5
9·53	66,048	340.8	265	210	73	20	24	70	110	119	3
10·03	69,457	340.9	265	210	74	20	24	70	108	110	3
10·13	72,817	335	265	213	75	20.5	24	70	115	116	2.5
10·23	76,192	337.5	258	195	72	20	24	70	108	116	3
10·33	79,588	339.6	258	213	75	21.5	24	70	108	115	3.5
10·43	83,024	343.6	265	213	77	22	24	70	115	120	3
Mean.	$\frac{20,384}{60}$	= 339.7	262.2	209	74.2	20.4	24	70	110.5	116.1	2.7

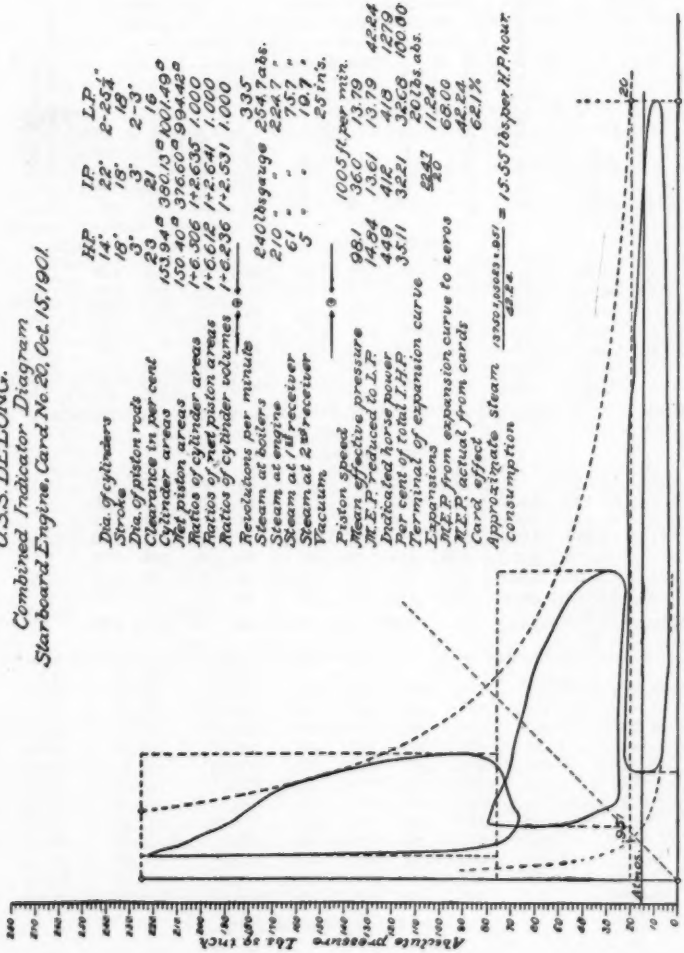
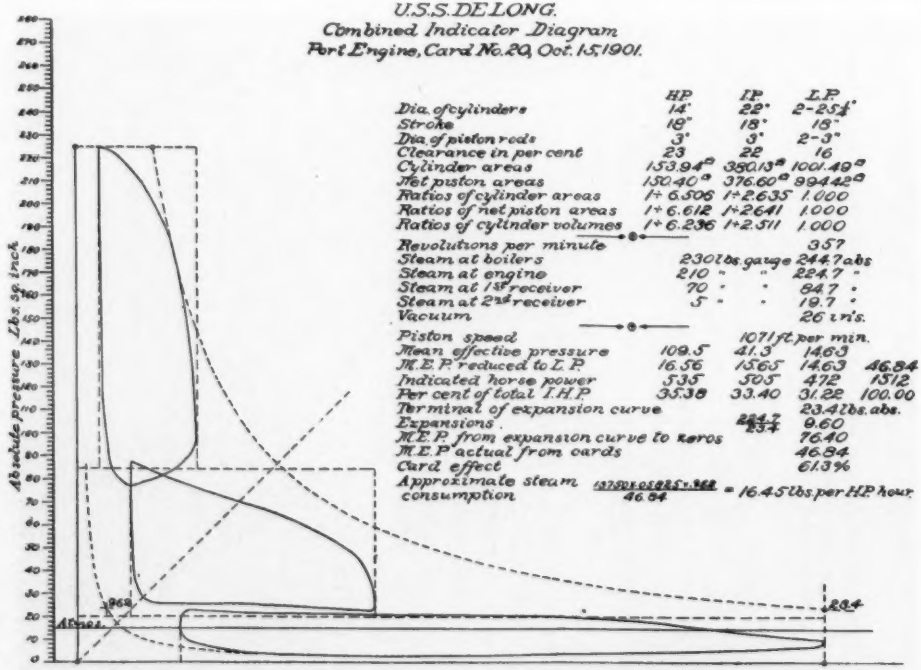

U.S.S. DELONG.
Combined Indicator Diagram
Starboard Engine. Card No. 20, Oct. 15, 1901.
H.P. I.P. L.P.
Dia. of cylinders 14" 22" 2-25½"
Stroke 18" 18" 18"
Dia. of piston rods 3" 3" 2-3"
Clearance in per cent 23 21 16
Cylinder areas 153.94 sq. in. 380.13 sq. in. 401.492
Net piston areas 130.40 sq. in. 376.60 sq. in. 994.425
Ratios of cylinder areas 1+6.306 1+2.635 1.000
Ratios of net piston areas 1+6.612 1+2.641 1.000
Ratios of cylinder volumes 1+6.236 1+2.531 1.000
Revolutions per minute 240 lbs gauge 335
Steam at boilers 210 " " 224.7 "
Steam at engine 61 " " 75.7 "
Steam at 1st receiver 5 " " 10.7 "
Steam at 2nd receiver 25 in's.
Vacuum
Piston speed 1005 ft. per min.
Mean effective pressure 98.1 36.0 13.79
M.E.P. reduced to L.P. 14.84 13.61 13.79 42.24
Indicated horse power 449 412 418 1279
Per cent of total I.H.P. 35.11 32.21 32.68 100.00
Terminal of expansion curve 6.42 20 lbs. abs.
Expansions 26 11.24
M.E.P. from expansion curve to zero 68.00
M.E.P. actual from cards 42.24
Card effect 62.1%
Approximate steam consumption (3300 × 60 × 0.85) / 42.22 = 15.55 lbs. per H.P. hour
Absolute pressure Lbs. to sq. inch
Atmos.
Vac.

Plate No. 1.—INSERTED FOR COMPARISON WITH DATA OF "BLAKELY".

Plate No. 1.—INSERTED FOR COMPARISON WITH DATA OF "BLAKELY".



	HP	IP	LP	
Dia. of cylinders	14"	22"	2-25½"	
Stroke	18"	18"	18"	
Dia. of piston rods	3"	3"	2-3"	
Clearance in per cent	23	22	16	
Cylinder areas	153.94 □"	350.13 □"	1001.49 □"	
Net piston areas	150.40 □"	376.60 □"	994.42 □"	
Ratios of cylinder areas	1 : 6.506	1 : 2.635	1.000	
Ratios of net piston areas	1 : 6.612	1 : 2.641	1.000	
Ratios of cylinder volumes	1 : 6.236	1 : 2.511	1.000	
Revolutions per minute			357	
Steam at boilers	230 lbs. gauge		244.7 abs	
Steam at engine	210 " "		224.7 "	
Steam at 1st receiver	70 " "		84.7 "	
Steam at 2nd receiver	5 " "		19.7 "	
Vacuum			26 in's.	
Piston speed			1071 ft. per min.	
Mean effective pressure	109.5	41.3	14.63	
M.E.P. reduced to L.P.	16.56	15.65	14.63	46.84
Indicated horse power	535	505	472	1512
Per cent of total I.H.P.	35.38	33.40	31.22	100.00
Terminal of expansion curve			23.4 lbs. abs.	
Expansions		224.7 / 23.4	9.60	
M.E.P. from expansion curve to zeros			76.40	
M.E.P. actual from cards			46.84	
Card effect			61.3%	

Approximate steam consumption $\frac{(37.91 \times 0.225) + 3.48}{46.84} = 16.45$ lbs. per H.P. hour.

Plate No. 2.—INSERTED FOR COMPARISON WITH DATA OF "BLAKELY".

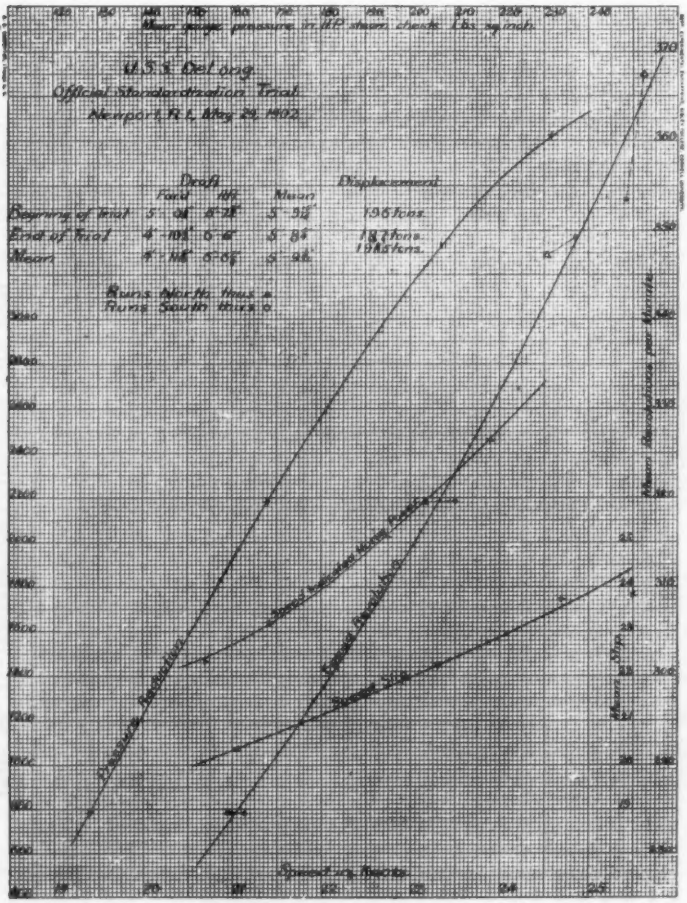


Plate No. 3.—INSERTED FOR COMPARISON WITH DATA OF "BLAKELY".

REPORTS ON TURBINE INSTALLATIONS.

STEAM YACHTS *LORENA* AND *TARANTULA*, AND STEAMER *TURBINIA*.

The following report, made to the Chief of Bureau of Steam Engineering, will be of interest to all readers on the practical results of steam turbine installations for marine propulsion, and is published with the hope that further observations from other sources may be received to add to the data already to be found in the JOURNAL.

NAVY DEPARTMENT, BUREAU OF STEAM ENGINEERING,
WASHINGTON, D. C., *October 1, 1904.*

Sir: The undersigned, having been appointed to investigate and observe the operation of the steam turbine installations of the steam yachts *Lorena* and *Tarantula* and the passenger steamer *Turbinia*, have the honor to submit the following reports:

While it may now be considered practically settled that the experimental stage of the Parsons steam turbine for marine propulsion is passed, it seems appropriate to add, however, that there yet exists some uncertainty as to its efficiency, especially under reduced speed conditions. In its favor it may be stated that, mechanically considered, it possesses decided reliability, and that this is combined with general simplicity in operation. This was borne out to an appreciable degree in the performance of the beforementioned steamers, and the same, it is believed, has been the general experience gained so far with this type of motor. This comment, however, must not be construed to imply certain immunity against accidents with the turbine, for such is not the case, and will be referred to later.

To those who may review this report in the expectation of obtaining additional knowledge on turbine propulsion, a subject

yet but slightly exploited, its contents may appear incomplete. In explanation, however, it should be mentioned that actual results of economy in steam consumption and speed, or efficiency in general, could not well be obtained, owing to the conditions prevailing under which this matter was accumulated. Facilities were courteously extended by the owners of the ships in question in response to the Bureau's request for permission for its representatives to observe and take notes of the turbine installations, but, as may readily be understood, no interference in the regular routine of the ship was to be asked for. Neither has there been included in this report any matter pertaining to the general construction or design of the turbine, nor have any of its apparent advantages or disadvantages been pointed out. These themes have been made the subject of discussion in various articles, and are, therefore, well known.

ON YACHT *LORENA*, AUGUST 9, 10.

The *Lorena* is a sea-going yacht built by Ramage & Ferguson, of Leith, Scotland, for Mr. Amzi L. Barber, of New York, and is fitted up and equipped for cruising around the world. The turbines were furnished by the Parsons Marine Turbine Company, Wallsend-on-Tyne.

Hull.—Length over all, 300 feet; length on load line, 253 feet; breadth, 33 feet 3 inches; draught, about 13 feet. Designed speed, 16 knots. Maximum speed on trial, 18 knots. Coal bunker capacity, 475 tons.

Engines.—Three Parsons compound steam turbines of an estimated combined horsepower of about 4,000.

Boilers.—Four cylindrical, single-ended boilers, 14 feet diameter by 12 feet 1½ inches long, with three furnaces in each, 42 inches in diameter. Grate surface, total, 217 square feet; heating surface, total, 8,560 square feet.

Howden forced draft with ¾-inch air pressure in the ash pits. The boilers are not fitted with means for superheating the steam.

Auxiliaries.—Two surface condensers; two Simplex Weir feed pumps; two combined air and circulating pumps; two Simplex Weir oil pumps for forcing oil through main bearings of tur-

bines; one evaporator; one feed heater; one auxiliary condenser; one donkey pump for general purposes; one fresh-water pump for tank purposes; two dynamo engines; one salt-water pump for bath; one feed tank; two Howden forced-draft blowers; one filter box; one Allen dense-air ice machine. Steam-steering engine, capstan and anchor engines and deck engines were also placed in the usual positions in the ship.

Screw Propellers and Shafting.—There is placed on each of the three shafts one bronze screw propeller, of which the center screw is 56 inches diameter and each wing screw 48 inches. All have three blades, solid with the hub. Diameter of line shafting, $4\frac{1}{2}$ inches.

Type of Turbines.—The turbine installation in this ship consists of three machines of the Parsons type, of which one forms the H.P. turbine and each of the other two a L.P. turbine, each turbine operating one shaft with its screw propeller. The wing turbines may be worked each entirely independently of the other, both as regards direction of motion and speed of revolution.

The reversing turbines are placed at the exhaust end, within the casing of each L.P. turbine, and, when not in use, revolve with the regular rotor for ahead motion.

The exhaust end of the H.P. turbine is joined to the steam end of the L.P. turbine through a receiver pipe containing a spring-loaded non-return valve to prevent any flow of steam to the H.P. turbine when the L.P. turbines are being used for maneuvering purposes. The H.P. turbine is not furnished with a backing device, and is, therefore, idle at such intervals. Slip joints are fitted to the receiver pipes to provide for contraction and expansion.

By-pass valves, admitting live steam direct at some point beyond the regular inlet valves, are placed on the H.P. casing, and will thus allow for a considerable increase in horsepower should extraordinary conditions require same.

Disposition of Turbines.—The location of the turbines is well amidship, and thus, owing to the non-existence in the engine room of side bunkers, with their fore-and-aft bulkheads, adequate athwartship space is provided. This athwartship space is essential in order to bring about such disposition of the turbine

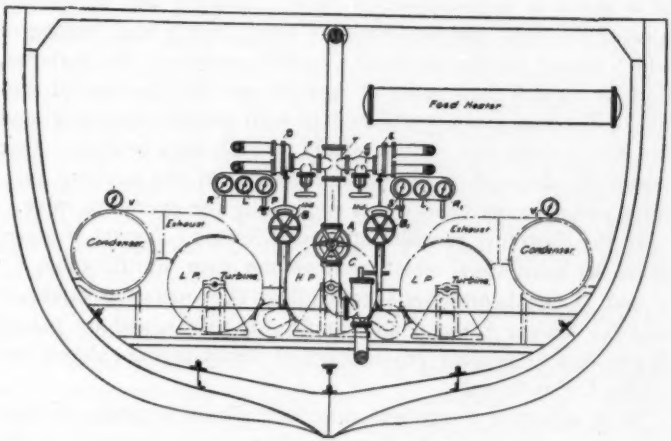
machinery as to render it more readily accessible, and also to obtain the most direct pipe connections between turbines and condensers. Apart from this, however, it is readily understood that, for maneuvering purposes and operation of the turbines in general, it is of considerable advantage to so assemble the operating gear that the working of said turbines is made possible from one working platform, and therefore by the smallest number of men.

All three turbines are placed abreast, with the H.P. turbine in the center and a L.P. turbine at each side, the main condensers being located outboard, one at each side of the ship and directly opposite the L.P. turbines. The run of the steam and exhaust connections is by this arrangement most readily provided for, the machinery as a whole at the same time taking up less room and being probably less obstructive than would be possible with any other disposition of turbines.

Steam and Exhaust Connections.—The main steam pipe enters the engine room close under the main deck beams, and is furnished with a cross fitting, *T* (see Sketch I), the side branches of which connect with stop valves, to which are bolted operating valves, each with two branches, one leading to the steam end of the L.P. turbine and the other to the reversing turbine.

The exhaust passages to the condenser being of necessity very large (in the case of the *Lorena*, about 52 inches wide by 23 inches high), it seems of imperative importance, both on account of the vacuum to be maintained and the features of construction involved, to make this connection as short and direct as possible. This may be best accomplished by an arrangement similar to the one described above.

Working Platforms.—The engine-room floor, which also forms the working platform, is on one level in the fore part of the engine room, where it is located on a line convenient for operating the valves and somewhat below the center of the turbine casings. Observation makes it at once apparent that no galleries or platforms are needed for the care or operation of the turbines, but such platforms were arranged at different places in the engine room because of the location of certain auxiliary machinery.



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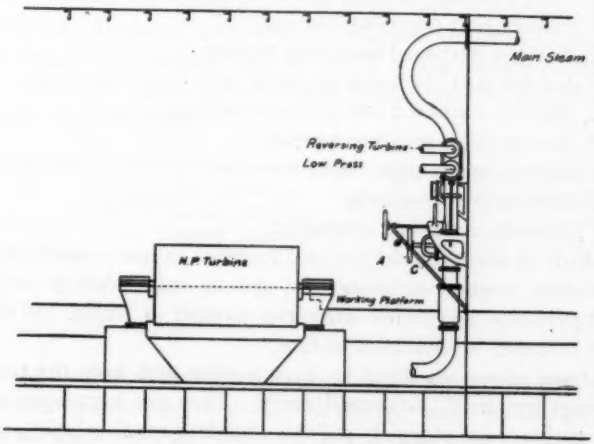


Sketch No. I
Scale 1"=1' Aug 20-04

'Lorena'

Operating Gear.—The gear for operating the turbines consists of a series of inter-connected valves, pressure and compound gauges and dials, the simultaneous manipulation and reading of which impart to the operators a perfect control of the turbines, both as regards their speed of rotation and the direction of motion. Tachometers are attached to each turbine separately, and are driven from the turbine shafts at each after bearing. One repeating telegraph is placed at each side of the working platform and near the hand wheel controlling the operating valve.

In the diagrams herewith appended, Sketch I, *Lorena*, *A* represents the hand wheel which controls the main throttle valve, *C*; *B* and B_1 the hand wheels controlling the operating valves, *D* and *E*. Valves *F* and *G* are simple stop valves, and are placed in position to prevent any leakage of steam to the exhaust end of the L.P. turbines.

With regard to the gauges, they were placed in groups of three on each gauge board, the vacuum gauges being mounted on the condensers, and are designated as follows:

R denotes port reversing turbine.
R_1 denotes starboard reversing turbine.
L denotes port low-pressure turbine.
L_1 denotes starboard low-pressure turbine.
P denotes high-pressure turbine.
S denotes steam pipe above throttle.
V denotes port condenser.
V_1 denotes starboard condenser.

With an arrangement of three turbines as here described, two operators seemed necessary for speedy maneuvering, but this will probably also suffice when the number of shafts, and therefore turbines, is increased to four.

Drain valves are fitted to each turbine and keep the turbine casings free from condensed water. They are kept open when the turbines are stopped, and thus the danger of stripping vanes by contact with a solid mass of water when starting up suddenly is greatly reduced. These drains lead to the channel ways of the air pumps, which are kept running continuously.

For the maintenance of any speed condition, the operator was governed solely by the readings on the gauges, which to him had become the index of revolutions and, therefore, speed.

Thrust Shaft and Bearings.—There are fifteen thrust collars on each thrust shaft $\frac{5}{16}$-inch thick and $\frac{3}{4}$-inch wide with an outside diameter of 6 inches. The thrust shaft forms part of the turbine shaft and is enclosed in the forward turbine bearing. The thrust block is part of this forward turbine bearing and is composed of concentric brass rings forming the thrust surface. This bearing is split on the center line, the lower part taking up the ahead thrust, the upper the backing thrust. The main bearings are all lined with white metal.

Performance.—Owing to some unfortunate circumstances entirely beyond the control of Mr. Barber, the owner of the *Lorena*, it was found inexpedient to arrange for any performance which would even remotely compare with a full-speed trial. From observations obtained during the short run from New York City to Tompkinsville, S. I., a generally splendid performance of the turbine engines was noted, no vibration or noise of any kind was discernable. A smooth motion and a minimum of attention seem to be among the principal characteristics of the turbine installation. The engine data with reference to this run were as follows, two boilers under steam:

Steam pressure at boilers, pounds	180
in steam pipe, pounds	160
at H.P. turbine, pounds	100
L.P. turbine, pounds	20
Vacuum, inches	27
R.P.M. center turbine	300
wing turbines	350
air and circulating pumps	100

For full speed, which corresponds to about 500 R.P.M. with the center turbine and 600 R.P.M. on the wing turbines, the gauge readings were said to be about as follows:

At boilers, pounds	180
H.P. turbine, pounds	150
L.P. turbine, pounds	25

For half speed:

At boilers, pounds	180
H.P. turbine, pounds	50
L.P. turbine, pounds	5

ON PASSENGER STEAMER *TURBINIA*, AUGUST 11, 12.

The steamer *Turbinia*, owned by the Turbine Steamship Company, of Hamilton, Canada, was built by Hawthorn, Leslie & Co., Newcastle-on-Tyne, the turbines having been furnished by the Parsons Marine Turbine Company, Wallsend-on-Tyne. It maintains a scheduled passenger service between Hamilton and Toronto, making three daily runs in each direction, having charter allowing 1,500 passengers to be taken on.

Hull.—Length over all, 262 feet; breadth, 33 feet; draught, loaded, 10 feet; displacement, 1,200 tons; speed, ordinary running, 20 knots; bunker capacity, 110 tons.

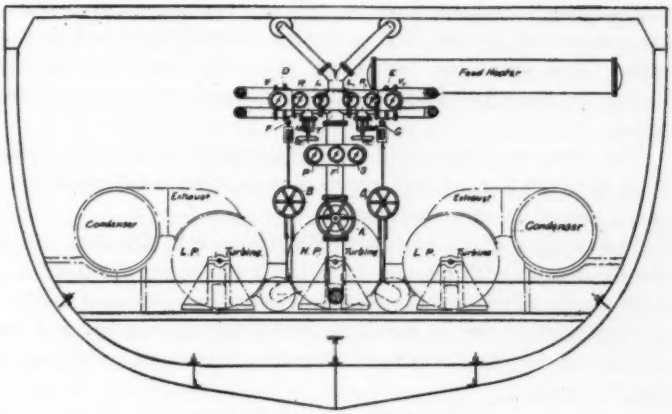
Engines.—Three Parsons compound steam turbines of an estimated combined horsepower of about 3,300.

Boilers.—Two cylindrical Scotch single-ended boilers, placed fore-and-aft, with two firerooms. There are four furnaces in each boiler. Total grate surface, 182 square feet. Closed fireroom with 1½-inch air pressure. No means for superheating the steam exists.

Auxiliaries.—Two Simplex Chapman and Clarke feed pumps, placed in engine room; two Simplex vertical oil pumps; two combined air and circulating pumps; two blowers, placed in boiler-room casing; one donkey pump for fire and other purposes; one exhaust feed-heater connecting to all auxiliary exhaust mains; two surface condensers; one dynamo engine; one steam-steering engine and steam capstan.

Screw Propellers and Shafting.—One carefully balanced and highly polished bronze screw propeller was placed on each shaft. They were all of same diameter, or 49 inches, with a uniform pitch of 42 inches. The shape of each blade appeared almost a perfect circle. For ahead motion the starboard and center screw turn to right, the port to left.

All line shafting is 4 inches diameter.



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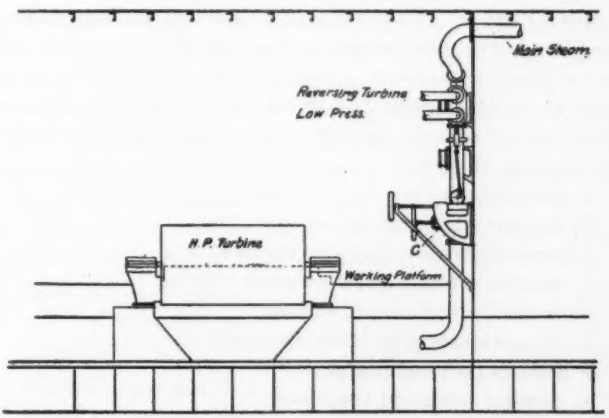


Sketch No II.
Scale 1" = 1' Aug. 22-04.

*Turbinia.

Type, Arrangement and Manipulation of Turbines.—As in the *Lorena*, there are three Parsons turbines operating three shafts, the center one by the H.P. and each wing shaft by a L.P. turbine. The speed of revolution was, however, considerably higher in these turbines, as will be noticed by comparing the tables.

The same arrangement of reversing turbine exists in the *Turbinia* as in the *Lorena*, and practically an identical disposition of steam and exhaust connections.

The location of the turbines with reference to the ship and of the condensers with relation to turbines was in the main alike in both ships. The working platform, operating gear and method of manipulation was in substance and principle uniform, and the description for the *Lorena* will therefore answer to condition on the *Turbinia.*

In the diagrams herewith appended, Sketch II, *Turbinia, A* represents the hand wheel which controls the main throttle valve, *C; B* and B_1 the hand wheels controlling the operating valves, *D* and *E.* Valves *F* and *G* are simple stop valves, and are placed in position to prevent leakage of steam to the exhaust end of the L.P. turbines. The gauges are placed in groups of three on three different boards, and are located in places where they may be seen at a glance. The following table designates the purpose of each:

R denotes port reversing turbine.
R_1 denotes starboard reversing turbine.
L denotes port low-pressure turbine.
L_1 denotes starboard low-pressure turbine.
P denotes high-pressure turbine.
S denotes steam pipe above throttle.
V denotes port condenser.
V_1 denotes starboard condenser.
F denotes feed heater.

In approaching the docks at either terminal two men were required to stand by to follow up the engine-room signals received, but while running uninterruptedly only one man was seen in the engine room. When order to slow down is given

the main throttle (C) alone is used, and is shut off completely when maneuvering is anticipated. Then instead valves F and G are opened, putting the operating valves in readiness. For ahead hand wheels B and B_1 are turned to the right, or as may be indicated by dial hands, and for backing the reverse operation takes place. Either wing turbine may be worked independently of the other in the same or in the opposite direction.

The backing power seemed adequate enough for all purposes of handling and bringing the vessel to a stop in time for landing without undue prolongation of previous slowing down of the speed.

Drain valves connecting the lower casings with the air pumps are fitted to all turbines for the same purpose as previously described in *Lorena*.

Thrust Shaft and Bearings.—Thrust shafts and bearings were arranged similarly to those on *Lorena*, the description of which will in the main answer for the *Turbinia*.

Performance.—The general smooth and noiseless performance of the turbines, and, in consequence thereof, an almost complete absence of ship vibration, as well as the ease with which maneuvering is accomplished, render the steam turbine particularly desirable for ships of this class. During the entire three runs participated in the turbines worked well, and it is said since placed in commission had neither caused delay nor had been in want of repairs of any kind.

The engine data with reference to certain runs en route Hamilton—Toronto—Hamilton were as follows:

Steam pressure at boilers, pounds	160
in steam pipe, pounds	140
at H.P. turbine, pounds	115
at L.P. turbine, pounds	40
Vacuum (condensers), inches	26½
(astern turbines), inches	28
R. P. M. center shaft	640
starboard wing shaft	680
port wing shaft	688
Pressure at oil pump, pounds	7
Temperature injection water, degrees Fahrenheit	52
discharge water, degrees Fahrenheit	94

After about one and a half hours running the steam pressure had gradually dropped fully ten pounds below starting conditions, but whether this was due to firing conditions or insufficient boilers cannot with certainty be stated. It is thought, however, that the cause may be ascribed to the latter.

ON YACHT *TARANTULA*, SEPTEMBER 8, 9.

The *Tarantula* was designed and built by Messrs. Yarrow & Co., Limited, London, and is used by its present owner, Mr. W. K. Vanderbilt, Jr., principally for the purpose of quick transportation for himself between his place of business in New York and his residence at Great Neck, Long Island Sound.

On account of the similarity of its hull with the general type of torpedo boats, the turbine installation of the ship in question possesses particular interest, especially when it is noted that a sister ship, a torpedo boat of identical lines and dimensions, also built by Messrs. Yarrow & Co., was fitted with a combination of a reciprocating engine and turbines of the Rateau type. The average speed on several trial runs with this boat was about 26 knots, when the turbines developed 2,000 horsepower, and reciprocating engine 250. The *Tarantula* is said to have developed 25½ knots on trial.

Hull.—Length, 152 feet 6 inches; breadth, 15 feet 3 inches; displacement, 140 tons; speed, average running, probably 22 knots, which, under extraordinary conditions, may, for a short time, be increased one or two knots.

Engines.—Three Parsons compound steam turbines of an estimated combined horsepower of about 2,200.

Boilers.—Two Yarrow, small-tube type, with grates 7 feet 6 inches long. Total G. S., 66 square feet. Forced draft, 2½ inches air pressure, closed fireroom system.

Auxiliaries (*in Engine Room*).—One Blake donkey pump for general purposes, such as fire, washing decks, ash ejector, etc.

One auxiliary air and circulating pump.

One small pump for circulating water through turbine bearings.

Two oil pumps to maintain oil circulation in turbine bearings.

One 3½-kw. dynamo, 70 to 90 volts, and engine and switchboard.

Two surface condensers with scoop injection.

Two single-acting air pumps placed at after end of L.P. turbine and driven by gearing from its shaft.

One feed tank.

Auxiliaries (in Boiler Room).—One duplex double-acting Worthington (English) feed pump; one Forbes blower and engine; one feed heater; one ash ejector.

Screw Propellers and Shafting.—One propeller is fitted to each of the three shafts. Diameter of all, 37 inches, with a pitch increasing from 33 to 37 inches.

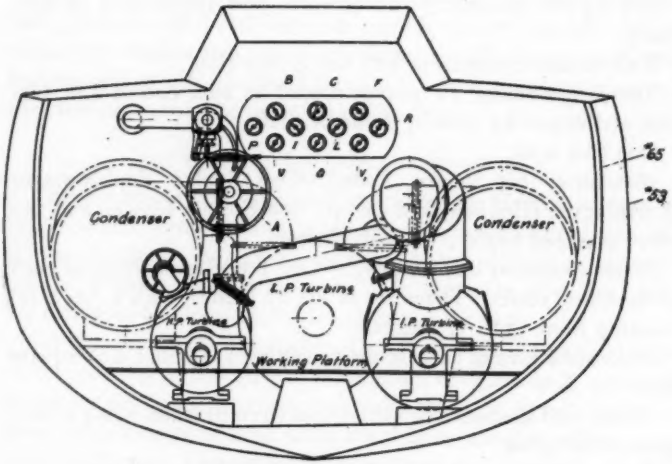
Helicoidal area of each screw propeller was about 4.92 square feet.

Center and starboard propeller turn to right when going ahead, port screw to left.

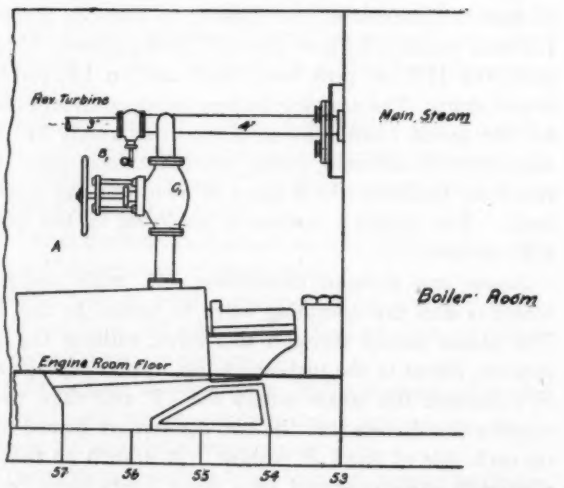
Line shafting connecting all turbines, 3 inches diameter.

Type and Disposition of Turbines.—The original arrangement of motors consisted of four Parsons turbines on three shafts, the L.P. and cruising turbine (forward) being connected to the center shaft, the H.P. on port wing shaft and an I.P. turbine on starboard shaft. The cruising turbine being considered unnecessary for the speed conditions employed (invariably full speed), was subsequently removed, giving abundant floor space between the two wing turbines, which space is now used for operating platform. The backing turbine is enclosed in the casing of the L.P. turbine.

Steam and Exhaust Connections.—A main steam stop valve, which is also the operating valve, is bolted to the H.P. casing. The steam passes through this valve, without the usual steam strainer, direct to the turbine casing. After passage through the H.P. turbine the steam enters the I.P. and then the L.P., from whence it exhausts into the two condensers placed opposite, one on each side of the L.P. turbine. A branch on the main steam pipe, with valve operated by a lever, leads direct to the reverse turbine. A by-pass valve, admitting live steam direct to an intermediate stage, is bolted to the casing of the H.P. turbine. On



Section "65 Looking Forward.



Tarantula

Sketch No. III.
Scale $\frac{3}{8}$ = 1 ft.

the *Tarantula*, by opening this valve when the H.P. turbine shaft was running at about 1,000 R.P.M. an increase of some 300 revolutions was at once obtained, with a corresponding increase in horsepower and probably from one to two knots added speed; the steaming power of the boilers of course places a limit to the duration in the usage of this excess of power.

Working Platform.—This is located between the H.P. and I.P. turbines at the forward end of the engine room, convenient to the operating valves, the repeating telegraph and gauges.

Operating Gear and Manipulation.—The gear for operating the turbines consists of two valves, one for ahead motion, which is an ordinary globe screw stop valve, and one for backing, which is a balanced valve worked with a lever. These valves, together with the gauges, give to the operator perfect control of the turbines.

In Sketch III, appended, A represents the hand wheel, which controls the main stop or throttle valve C_1. Lever on backing valve is indicated by B_1, and the gauges are designated as follows:

B denotes boilers.
P denotes high-pressure turbine.
I denotes intermediate-pressure turbine.
L denotes low-pressure turbine.
R denotes reversing turbine.
O denotes oil pump.
F denotes feed line.
V denotes port condenser.
V_1 denotes starboard condenser.
C denotes clock.

It is quite within the abilities of one man to operate all the turbines and attend to any manipulation required when maneuvering. Before starting up, all turbine drain valves to the lower turbine casings are opened, the discharge from which, leading into the air-pump suction, frees the casing of condensed water.

When order to go ahead is given the main throttle is opened, the valve connecting the reverse turbine being closed. The amount of valve opening, corresponding to a certain quantity of steam admitted to the casing, regulates the number of revolutions of the turbine, the approximate number of which is ascertained by observing the various pressures indicated by the

gauges, certain pressures corresponding to certain speeds of revolutions.

When order to go astern is given the main throttle is closed and the valve connecting the reverse turbine is opened. Although only the one screw furnishes backing power, while all three impart motion ahead, it is stated that the ship may be brought to a dead stop in from 38 to 42 seconds when running at about 24 knots. The arrangement of these turbines with their operating valves necessitates simultaneous running of all screws when going ahead, backing with one and going ahead with the others not being possible simultaneously.

Drains to H.P. and I.P. are closed immediately after turbines have been started. The L.P. drain, which is placed in the exhaust cavity, having no valve, remains open continually.

Tachometers are connected to each turbine by gearing, and the revolutions are thereby read off directly.

Performance.—The following data and notes were taken during a run up Long Island Sound from New York to Great Neck: The turbines worked without vibration and with but slight noise, no motion due to the action of machinery or propellers being discernible in any part of the ship.

The steaming capacity of the boilers is not sufficient to supply the turbines with the steam needed for ship speed desired, and they are to be replaced by another type of water-tube boilers giving about twice the present grate area.

Pressures, revolutions and other data are given below. All boilers (2) under steam:

Steam pressure in boilers by gauge, pounds	225
steam pipe by gauge, pounds	215
H.P. turbine inlet, gauge, pounds	200
I.P. turbine inlet, gauge, pounds	34
L.P. turbine inlet, inches vacuum	8
Starboard condenser, inches vacuum	21
Port condenser, inches vacuum	21
Astern turbine, inches vacuum	20
R.P.M. center shaft	1,000
starboard wing shaft	920
port wing shaft	930
air pumps	100
Pressure in oil main, pounds	5½

Although the estimated horsepower of the *Tarantula* was about 2,200, it is probable that not more than 1,500 or 1,600 were developed on her recent run. With pressure conditions as existing throughout the turbines, carrying 8 inches vacuum at the steam end and about 21 inches at exhaust end of the L.P. turbine, this turbine does not seem capable of having developed its share of the total power. When the by-pass valve to the H.P. casing was placed in operation the steam end of the L.P. turbine worked with atmospheric pressure.

Notice should be taken of the poor vacuum, although this was probably a result of a combination of circumstances—in which an inferior air pump and a bad arrangement for injection water may be counted.

Thrust Shaft and Bearing.—The thrust shaft has 14 thrust collars ¼ inch thick, 4 inches outside diameter, the inside diameter being 3 inches. The thrust shaft, like those described in *Lorena* and *Turbinia*, forms a part of the turbine shaft at the forward bearing. In the thrust bearing, which is split along the center line, the lower half is solid with the turbine casing and not adjustable, while the upper half, or the cap, may be shifted lengthwise by means of an adjusting screw, and is shown in Sketch IV.

NOTES IN GENERAL.

1. With regard to the disposition of turbines and the arrangement of machinery and piping in general, the design should provide for the ready removal of the top turbine casings. This is essential for examination and for the repair of the vanes should they by accident become damaged. Instances of vanes having been stripped from the rotor with this type of turbine when installed in ships are known to have occurred in at least two cases, and this contingency, although remote, should be taken into account in designs with turbine machinery as much as provisions for the examination of cylinders and removal of pistons in a reciprocating engine.

2. As regards space needed, this, at least with a Parsons turbine installation, is no less than for the reciprocating engine, as the following figures will show approximately.

The aggregate power of the three turbines in the *Tarantula* under the best conditions would probably equal 2,250 horsepower with an average speed of rotation of about 1,200 R.P.M. The length of the engine room is 21 feet 8 inches × the whole width of the ship (a mean of 15 feet), and the volumetric space occupied by the three turbines, together with the condensers, will be about .1 cubic foot per horsepower. Projected area of same, which will nearly correspond to the floor space occupied, will be about .05 square foot per horsepower. The corresponding figures in U. S. T. B. *Ericsson* is for volume .35 and for floor space .035. Broad ships with considerable width of engine room seem more suitable than those of a narrow type, since arrangements of turbines with condensers placed outside possess advantages over other arrangements with condensers put above or between the turbines.

3. Although there were no direct data obtainable as regards the general efficiency of the machinery, or particularly the steam used by the turbines, it may be inferred from statements made by those directly interested, such as the owners, that the general economy is thought to be as good as if reciprocating engines had been fitted to these ships. The *Turbinia* is said to use about 2½ tons of coal per hour and the *Lorena* about 25 tons per day for 13 knots steaming. As no oil is used, except in the main bearings, and which is there used in continuance, the saving from this source is considerable.

4. Since minor attention only is required during the time of operation, few adjustments being necessary and little overhauling generally, turbines, judged by such considerations, are especially well adapted for propulsion of ships.

5. With large installations by splitting the power on several shafts certain advantages appear, beside those claimed to exist for purely navigating purposes, in the greater combined efficiency of propeller and turbine, due to the fact that this efficiency is more readily obtained with smaller propellers and faster turbines.

6. If possible the arrangement of propellers should be such as to allow more liberal space between hull and tip of blades in

turning, the higher number of R.P.M. being very apt otherwise to cause considerable vibration of the hull at the stern.

7. It is also of imperative importance to produce the greatest possible accuracy in the weight balance of the propellers and to secure an absolutely equal pitch at corresponding points of each blade.

8. Although a high vacuum is of the greatest benefit to the turbine, too great a sacrifice in weight and space need not be made to accommodate an extraordinarily large condensing plant. Twenty-seven and one-half inches vacuum seemed readily obtained with the class of equipment now commonly used.

9. Owing to the close proximity of the turbine cylinders to the working floor, a higher degree of heat is experienced in the engine room near the working platform than with ordinary engines. Spacious engine-room hatches and large ventilators should be provided, and, at the same time, a system for efficiently lagging the turbines and condensers should be included in the design.

10. In all three of these vessels the auxiliary engines exhaust through a feed heater into the main condensers, and on the *Lorena* this could be by-passed at will into either one of the two condensers.

11. All shaft couplings are solidly bolted together, even at the ends connecting to turbine shafts.

12. Turbine glands are all steam packed and consist of annular spaces communicating with one another along that part of the shaft penetrating each turbine end. Air leakage into the turbines is thereby effectually prevented.

13. In a Parsons marine turbine the propeller thrust, both for forward and backing motion, is practically balanced, and therefore the thrust block required may be made of exceedingly small dimensions.

14. The thrust block, which is split along the center line, is so made that the upper part takes the thrust for backing motion while the lower serves a similar purpose for ahead. The cap being adjustible in a fore-and-aft direction confines the rotor in its longitudinal location, thereby minimizing steam leakage within

the turbine. Sketch IV shows the general features of the thrust block.

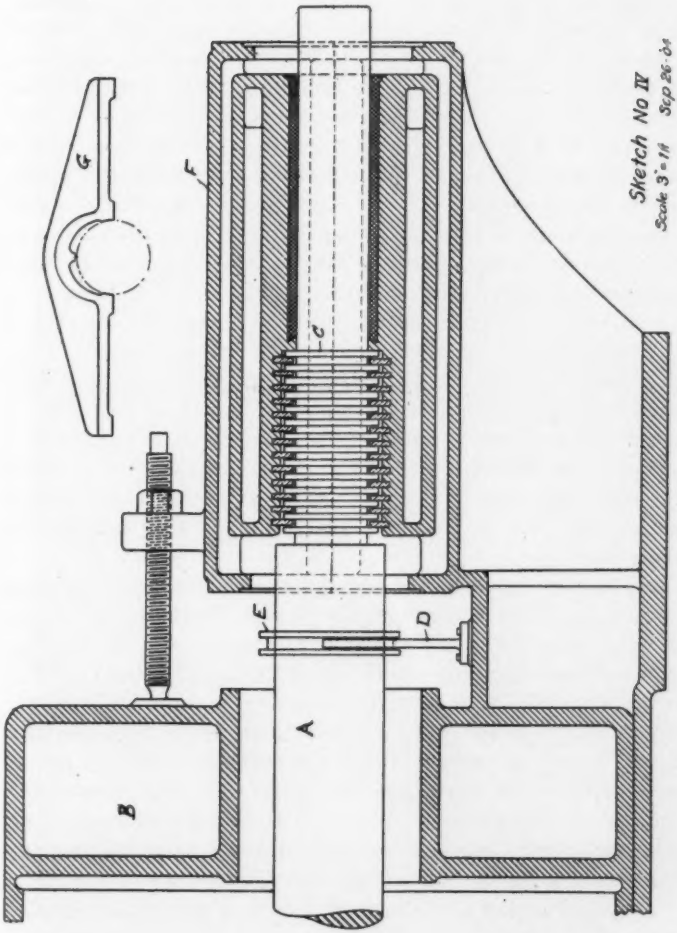
15. The oil pump is a very essential auxiliary in conjunction with a turbine installation, and is made in double units to additionally insure against breakdown, only one of these pumps being used at any one time. The complete disablement of these pumps would probably place the turbines out of commission. The end of each shaft bearing has a stuffing box, with a soft wick packing, which confines the oil within the bearing. A constant pressure from 6 to 8 pounds per square inch is kept in the oil pipes, creating continuous circulation of the oil fluid through the bearings and through the oil-settling tank. No cooling coils were used in this tank, but water circulation in the bearings themselves was arranged for.

16. On the *Lorena* each turbine is fitted with a centrifugal governor, which, by direct piping to the condenser, communicates with a governor valve, and is arranged so that in case of the shaft breaking or racing the steam is immediately shut off. Similar governor appliances were fitted to the turbines on the *Turbinia*, but were not connected up, and therefore not in use. A spring-loaded safety valve is also placed on each turbine casing. On the *Tarantula* none of these valves were in evidence.

17. No steam separators are used, but a steam strainer is placed in the main steam pipe to prevent any solid matter being carried over and into the more delicate parts of the turbine. In the *Tarantula* this steam strainer was fitted by the builders, but had been removed by the ship's crew.

18. It was asserted by the chief engineers of these vessels that no wear, either downwards in the bearings or fore-and-aft due to unequal thrust, had been detected during the time these ships had been in service.

19. On the *Lorena* and *Turbinia* the air and circulating pumps were of the usual Parsons design, consisting of a double-cylinder, high-pressure engine, driving both pumps, the engine crank shaft connecting direct to each. This makes a compact arrangement, occupying less room than would separately driven pumps, but mechanically is somewhat imperfect, and becomes less desirable


Sketch No IV
Scale 3"=1'
Sep 26-01
G
F
C
E
D
A
B

as the conditions in the ship limit the length of the air-pump connecting rod. The vacuum maintained, except where specially noted, was quite satisfactory throughout the condensers and turbine exhaust passages. It was better at the reverse turbine (when this was not in use) than elsewhere, which probably was caused by a more direct connection from that point to the air pump. In the *Tarantula*, as mentioned before, the air pumps were actuated by gearing from the L.P. turbine shaft (the pump running one-tenth R.P.M. of turbine) and consisted of two single-acting bucket pumps. The vacuum obtained with these pumps was very unsatisfactory, never amounting to more than about 22 to 24 inches. These pumps will be taken out and replaced by independent pumps.

20. The line shafting on the *Lorena* is inclined forward above the horizontal about 2½ degrees, and on the *Tarantula* about 4 degrees. All shafts are parallel in the plan view and the wing shafts are supported by struts at 13 feet centers.

21. The injection water in the *Tarantula* is arranged for by a scoop on the bottom of the hull, the inlet and outlet to and from the condenser being both at the after end. An auxiliary air and circulating pump worked the main condenser when the ship was lying still.

22. Sketch IV shows the methods employed to ascertain both circular and linear clearances, the former existing between the moving vanes and the inner side of the casing, the latter in the dummy packing rings or in the thrust collars. In the sketch *A* is the turbine shaft, *B* the front head of the turbine casing, while *C* are the thrust collars. *D* represents an index bolted solidly to the casing, the calipered distance between which and ring *E* on shaft give the exact position of the rotor with reference to the casing. Upper cap *F* of bearing is removed when gauging to ascertain the circular clearance. Gauge *G* is laid across the shaft, its lips resting on the machined flange.

23. A great part of the benefit arrived at by the adoption of turbines in securing smooth and noiseless running machinery is counteracted by certain auxiliaries, such as the blower engines commonly actuated by reciprocating engines. Such auxiliary engines, it seems, would be admirably suited for a turbine drive.

CONCLUSIONS.

1. The Parsons type of steam turbine may be fitted to ships for propelling purposes with satisfactory results equal, in general, to those found with reciprocating engines, the turbine possessing many advantages in detail and operation.

2. When fitted in ships doing much service at low speeds for extended periods of time, separate cruising turbines must be provided to insure economy.

3. Surface space, it seems, cannot be saved with this type of turbine running at speeds suitable for ship propulsion.

4. Some saving in weight may be gained by substituting turbines for reciprocating engines in ships, the amount being governed by the rotative speeds employed in running the propellers.

5. With the power transmitted through three or four shafts a gain in combined propeller and turbine efficiency is obtained and should, if ship conditions permit, be made use of with this type of turbine.

6. Condensers and air pumps must be made of ample proportions and of type to insure at least 27½ inches vacuum, anything below which should be considered unsuitable in connection with turbines.

The foregoing notes and conclusions, although especially referring to the turbine installations of type mentioned and of the ships in question, will, in the main, it is believed, be equally applicable to other well-known types of turbines.

Very respectfully,

A. B. CANAGA,
Commander, U. S. Navy.
ERNEST N. JANSON,
Of the Bureau of Steam Engineering,
Navy Department.

THE CHIEF OF THE BUREAU OF STEAM ENGINEERING,
Navy Department.

UNITED STATES ARMORED CRUISER *COLORADO*.

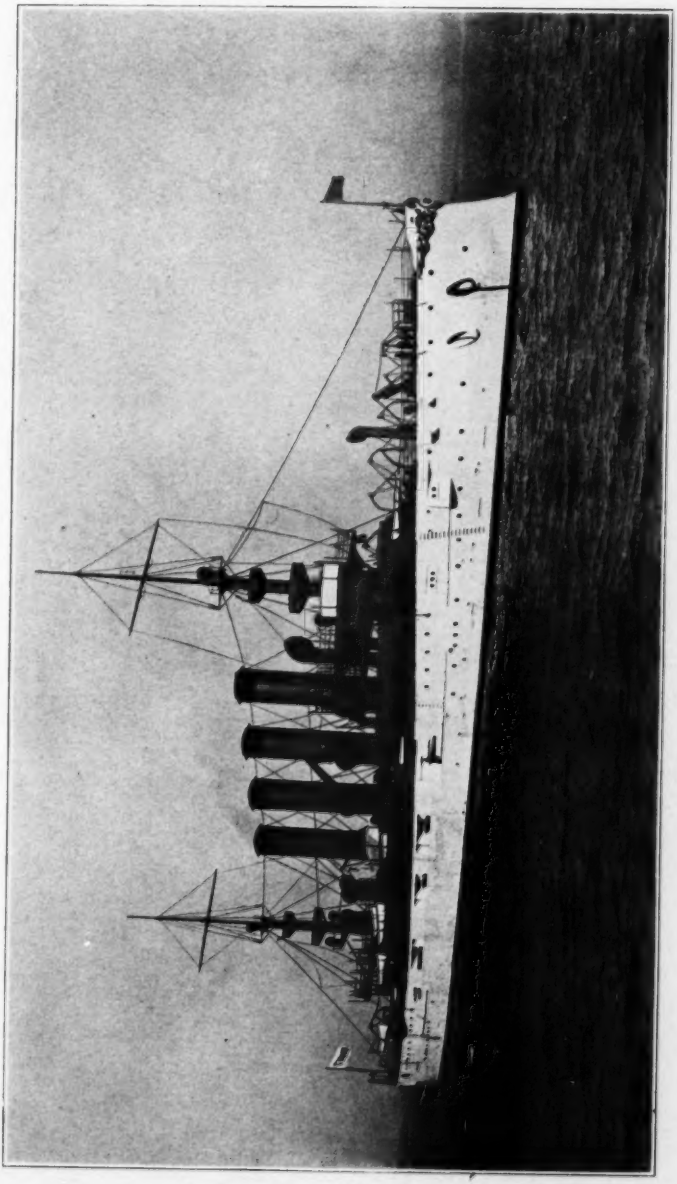
DESCRIPTION OF VESSEL.—OFFICIAL TRIAL PERFORMANCE.

By Lieutenant Commander E. H. Scribner, U. S. N., Member.

The armored cruiser *Colorado*, is one of the six vessels of this class authorized by Congress in 1900; the contract was signed January 10, 1901. The original contract time expired January 10, 1904, and was extended ten months by the Navy Department. The vessel was launched April 25, 1903. The dock trial was held June 21st, 1904; contractors' trial took place off Delaware Breakwater (June 30th to July 3d, 1904), July 2, 1904, over a measured course 1¼ knots long. The results of this trial are shown by speed curves appended, Fig. 1. The vessel had been in fresh water fourteen months, but when docked October 15th, 1904, the bottom was found to be in excellent condition.

Principal dimensions:

Length between perpendiculars, feet	502
on L.W.L., feet	502
over all, feet and inches	504–0½
Beam extreme, feet and inches	69–6½
at L.W.L., feet and inches	69–6½
Ratio of length to beam	7.2189
Depth, molded, main deck, feet	41
Draught, normal, mean, feet and inches	24–1
mean, on trial	24–1
Displacement, normal draught, tons	13,780
trial, tons	13,785
per inch at L.W.L., normal draught, tons	57
Area midship section to L.W.L., normal draught, square feet	1,595
L.W.L. plane (draught 24 feet 1 inch), square feet	23,940
Wetted surface, square feet	43,011
Center of gravity of L.W.L. plane, aft of M.S., feet	6.56
buoyancy above bottom of keel, feet and inches	13–2½
aft of M.S., feet	1.03



U. S. Armored Cruiser "Colorado".

Transverse metacenter above center of buoyancy, feet	14.40
Longitudinal metacenter above center of buoyancy, feet	627
Coefficient of fineness block	.5753
of M.S.	.9574
L.W.L.	.6858
Cylindrical coefficients, longitudinal	.6009
vertical	.8389
Number of frames	124

Armor (Krupp steel):

Belt, 6 and 5 inches.
Deck, 1½ and 4 inches.
Side, above belt, 5 inches.
Athwartship, 4 inches.
Turret gun, 6½ and 6 inches.
Barbettes, 6 and 4 inches.
6-inch gun positions, 5 inches.

Main Battery:

Four 8-inch B.L.R.'s, 45 calibers in length;
Fourteen 6-inch R.F. guns, 50 calibers in length;
Eighteen 3-inch R.F. guns, 50 calibers in length.

Secondary Battery:

Twelve 3-pounders, semi automatic.
Four one pounders, heavy, semi automatic;
Four one pounders, heavy, R.F. guns;
Two 3-inch field guns;
Four machine guns, 30 caliber;
Six automatic guns, 30 caliber.

Torpedo Tubes (to be installed):

Two 18-inch submerged tubes, six torpedoes.

Cost and Requirements:

Contract price (Machinery $1,500,000 included), $3,780,000.
(This does not include armor, guns, ordnance, boats, etc.)
Guaranteed speed for four hours, 22 knots.
Air pressure in firerooms, allowed, 2 inches of water.

If the speed attained on trial was less than 22 knots, a penalty was to be inflicted at the rate of $50,000 per quarter knot between 21 and 22 knots; between 21 and 20 knots the penalty rate

was to be $100,000 per quarter knot. Failure to make 20 knots might reject the vessel.

Protection:

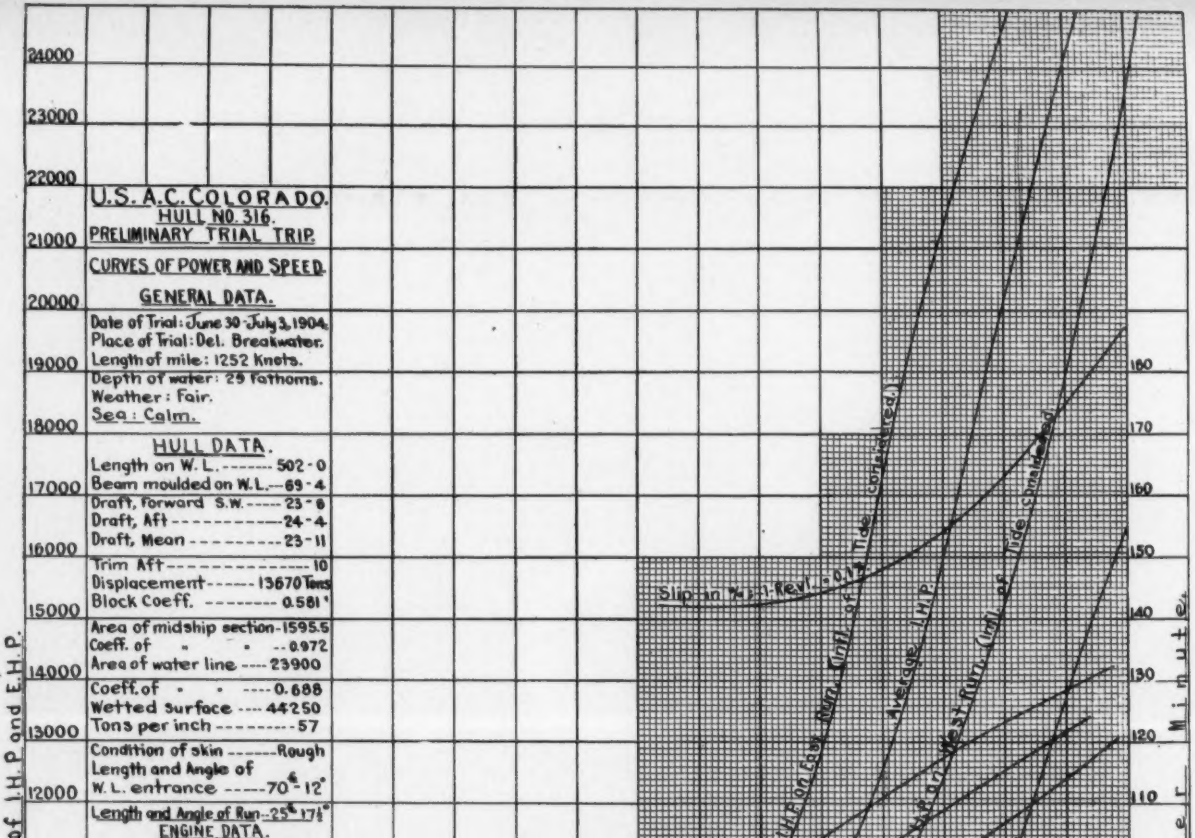
The protection of the vessel consists of a complete armor belt, 7½ feet wide, 6 inches thick for a distance of 4½ feet from the top, below which it tapers to 5 inches in thickness at the bottom.

This belt is stepped down in thickness beyond the machinery spaces forward and aft to 3½ inches. Above this belt the casemate armor, 5 inches thick, extends forward far enough to protect the 6-inch battery, and the same thickness of upper casemate armor is carried up to the upper deck in way of the four main deck 6-inch guns. The armored casemate, from the protective to the main deck, is completed by 4-inch armor, and this armor is also carried up to the upper deck for the protection of the 6-inch and 3-inch guns on that deck. The 8-inch turret guns are protected by a 6½-inch front plate, the rest of this armor having a thickness of 6 inches. The upper barbette is 6 inches thick, the lower barbette 4 inches, and the armored tube protecting the lower end of the turret hoists is 3 inches thick. A 9-inch conning tower with the same thickness of shield and a 5-inch steel armored tube are fitted. Of the above all armor 5 inches and over is Krupp hardened, all under 5 inches is Harveyized. The 3-inch guns are protected with 2-inch nickel-steel armor outboard, and with 1-inch nickel-steel splinter plates about 10 feet long.

Splinter bulkheads 2½ inches thick and 14 feet long are also fitted between the 6-inch guns of the gun deck casemate battery, but these have not been extended to enclose each gun in a separate casemate. The casemates for the main deck 6-inch guns are completed by 2-inch nickel steel armor worked from the ship's side inboard and then fore-and-aft to form each enclosure. The sloping side of the protective deck extends fore-and-aft the entire length of the vessel and is 1½ inches thick on the flat and 4 inches thick on the slopes, the upper plate being 100-pound nickel steel, including the forward and after turtle-back.

Electric Plant.—The dynamo rooms are two in number, ex-

XU


24000
23000
22000
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
U.S.A.C. COLORADO.
HULL NO. 316.
PRELIMINARY TRIAL TRIP.
CURVES OF POWER AND SPEED.
GENERAL DATA.
Date of Trial: June 30-July 3, 1904.
Place of Trial: Del. Breakwater.
Length of mile: 1252 Knots.
Depth of water: 25 Fathoms.
Weather: Fair.
Sea: Calm.
HULL DATA.
Length on W. L. ------- 502-0
Beam moulded on W. L. --69-4
Draft, Forward S.W. ----- 23-6
Draft, Aft ---------- 24-4
Draft, Mean ---------- 23-11
Trim Aft ---------- 10
Displacement ------ 13670 Tons
Block Coeff. -------- 0.581
Area of midship section-1595.5
Coeff. of " " -- 0.972
Area of water line ---- 23900
Coeff. of " " ---- 0.688
Wetted surface ---- 44250
Tons per inch ---------- 57
Condition of skin -------Rough
Length and Angle of
W. L. entrance -----70 6 - 12°
Length and Angle of Run--25 6 17½°
ENGINE DATA.
Slip in % = 1-Rev. × 0.12 / Tide corrected.
Average I.H.P. on 6 runs (1 hr.) at Tide smoothed
Average I.H.P. on 6 runs (1 hr.) at Tide smoothed
of I.H.P. and E.H.P.
160
170
160
150
140
130
120
110
Minutes

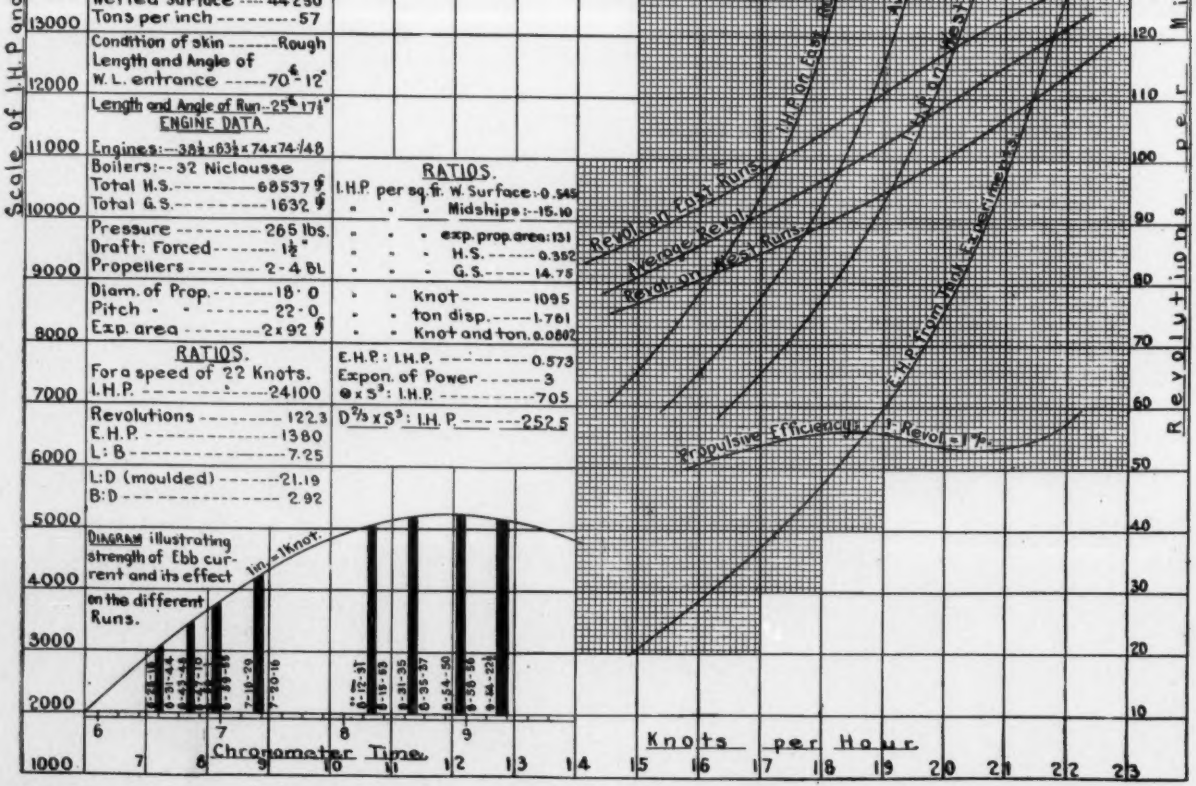


Fig. 1.—U. S. ARMORED CRUISER "COLORADO". POWER, SPEED AND PERFORMANCE CURVES; CONTRACTORS' TRIALS.

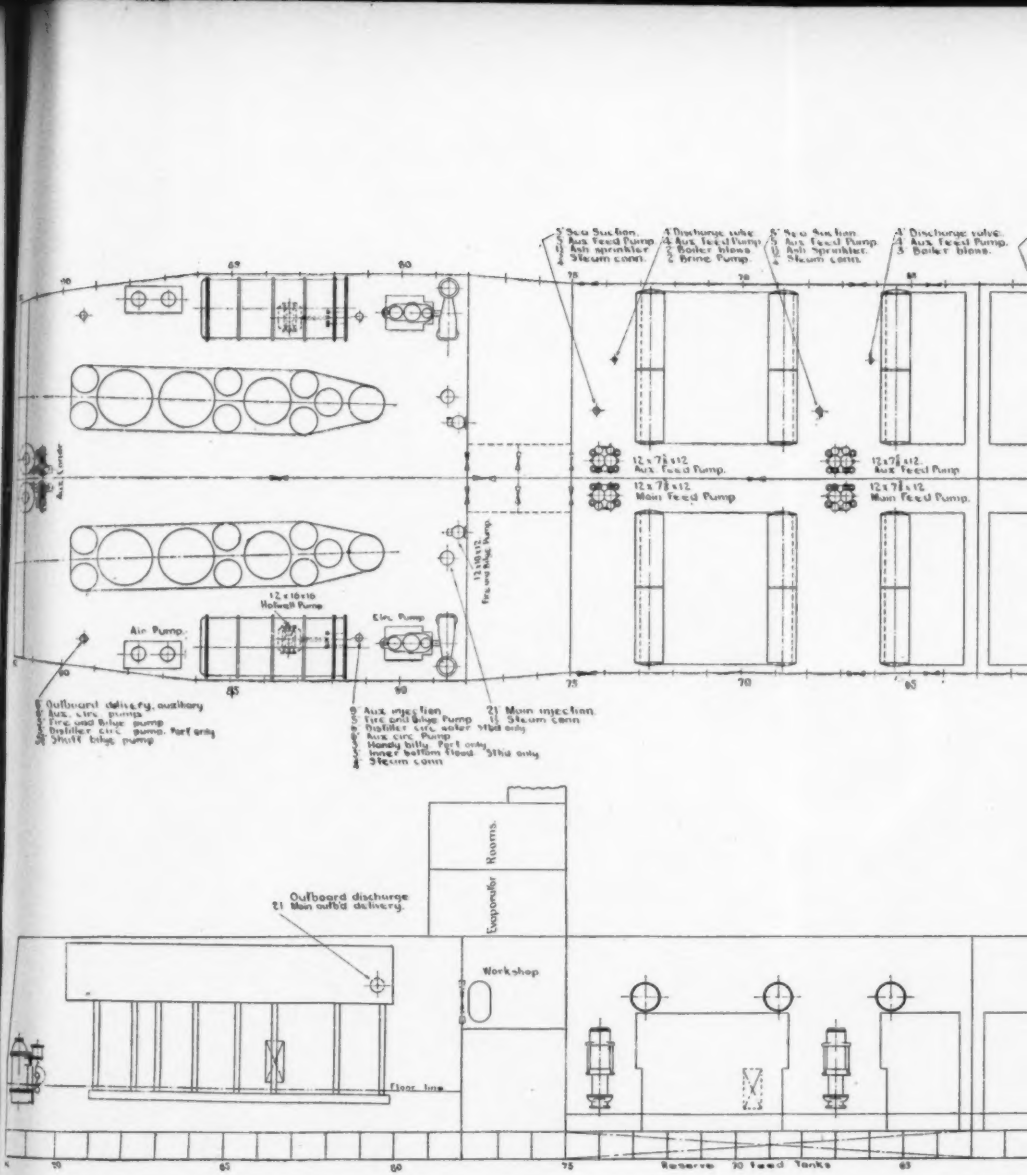
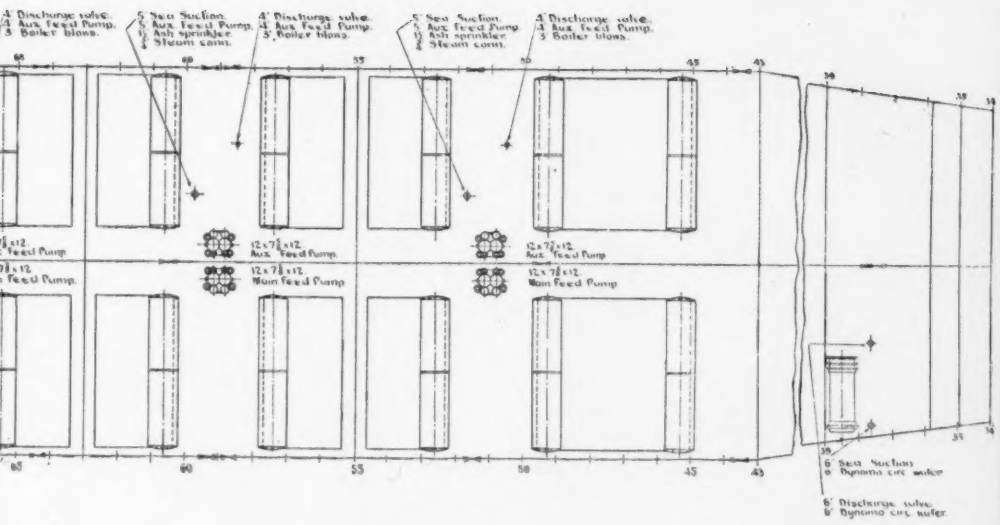
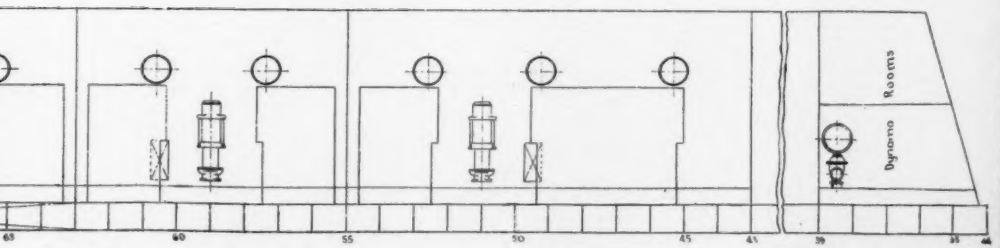


Fig. 2.—U. S. Armored Cruiser "Colorado". T





ORADO". TYPE ARRANGEMENT OF MACHINERY.

tending from the protective deck to the inner bottom and from frames 34 to 40. The plant consists of three 100-kw. and four 50-kw. sets, General Electric Company, giving a total ampèrage of 4,000. Three of the 50-kw. machines are located on the upper platforms, and the three 100-kw. and one 50-kw. sets are located in the hold. Nearly all wiring is run in enameled iron conduits. The dynamo engines are cross-compound, cranks at 180 degrees; steam, 150 pounds; voltage, 125. The 100-kw. set has H.P. cylinder, 10 inches; L.P. cylinder, 18 inches; stroke, 10 inches; revolutions (maximum), 350; I.H.P., about 140. The 50-kw. sets have H.P. cylinder, 7½ inches; L.P. cylinder, 14 inches; stroke, 8 inches; revolutions, 400, and I.H.P., about 70.

Name.	No. of lights.	Candle-power.	Description of light.
Bulkhead and drop lights	717	16	incandescent.
Bunker lights	52	16	incandescent.
S. P. ceiling fixtures	53	16	incandescent.
Deck lanterns	25	16	incandescent.
Portable lights	179	16	incandescent.
Turret-hood lights	6	5	incandescent.
Desk lights, silver and bronze	66	16	incandescent.
Side lights	2	16	incandescent.
Stay, top, towing and masthead lights	4	16	incandescent.
Battle lanterns	100	16	incandescent.
Instrument lights	9	5	incandescent.
Magazine lanterns	31	16	incandescent.
Cargo reflectors	6	16	incandescent.
Signal lanterns	11	16	incandescent.
Truck lights	2	16	incandescent.
Night signal set	2	32	incandescent.
Diving lamp	2	150	incandescent.
Arc lights	14	3½ ampères. 80 volts.	arc.

There are also six searchlights, 30-inch projectors, two on the flying bridge, about 42 feet above waterline; one on the searchlight platform of the foremast, about 78 feet above waterline; two on the lower searchlight platform of the mainmast, about 45 feet above the waterline, and one on the upper searchlight platform of this mast, about 78 feet above waterline.

ELECTRICALLY-OPERATED AUXILIARIES.

.....	Motors.		Rated H.P.
	No.	*H.P.*	
Ventilation, shunt wound	4 at	.5	2.
" " "	1 at	.75	.75
" " "	1 at	1.	1.
" " "	3 at	1.5	4.5
" " "	6 at	2.5	15.
" " "	2 at	2.75	5.5
" " "	3 at	3.5	10.5
" " "	1 at	4.	4.
" " "	2 at	5.	10.
" " "	2 at	12.	24.
" " "	2 at	18.	36.
Total ventilation	.....		113.25
Ammunition hoist, shunt wound	34 at	2.5	85.
Deck winch, series wound	7 at	30.	210.
Long-arm doors, compound wound	35 at	1.	35.
Fresh-water tank pump, shunt wound	2 at	1.5	3.
Laundry	1 at	6.	6.
Forward boat crane, hoisting, series wound	2 at	50.	100.
revolving, series wound	2 at	30.	60.
Aft boat crane, hoisting, series wound	2 at	20.	40.
revolving, series wound	2 at	15.	30.
Smoke blower, shunt wound	2 at	.5	1.
Whip hoist	4 at	3.5	14.
Centrifugal drainage pump, shunt wound	2 at	.75	1.5
Turret turning, shunt wound	4 at	15.	60.
8-inch ammunition hoist, shunt wound	4 at	11.	44.
elevating motor, shunt wound	4 at	3.5	14.
rammer motor, series wound	4 at	3.5	14.
elevating motor generator set	4 at	3.5	14.
Workshop motor	1		15.
	143 motors.		859.75

There are also to be installed :—five air compressors, two driven by 40-H.P. motors for charging torpedoes; two driven by 25-H.P. motors for smoke ejectors for turret guns; one 55-H.P. motor for operating pneumatic tools.

PROPELLING MACHINERY.

The *main engines* are four-cylinder, triple-expansion, vertical, inverted-cylinder, direct-acting, placed abreast in watertight compartments and separated by a middle-line bulkhead. The engine design provides for *outboard turning* screws when going ahead. The order of the cylinders, beginning forward, is high pressure, intermediate pressure, forward low pressure and after

low pressure. The H.P. and I.P. cranks are opposite, also the forward and after L.P. cranks, the second pair being at right angles with the first. The sequence of cranks is H.P., forward L.P., I.P. and after L.P. The framing of the engines consists of forged-steel columns trussed by forged-steel stays for the outboard side, and cast-steel housings of inverted Y shape for the inboard side, the latter carrying the crosshead guides of *cast iron*, slipper type, made hollow for cooling water. Each cylinder has one cast-steel inverted Y-frame housing (cast in two halves and bolted together) and two hollow forged-steel columns for its supports. The engines are tied to each other by athwartship braces at H.P. cylinders and after L.P. cylinders.

The *main valves* are worked by Stephenson link motion with double-bar links. There is one piston valve for each high-pressure cylinder and two for each intermediate and each low-pressure cylinder. The H.P. piston valves are cast iron; the I.P. and L.P. piston valves are built up of two cast-iron heads and a flanged steel-tube distance piece; each is fitted with a broad cast-iron packing ring, cut obliquely and secured so it may contract but not expand beyond the fitted size; the rings are held in place by followers of cast steel. Each of the main piston valves has a balance piston working in a cylinder on top of its valve chest. The valve-stem crosshead guides consist of cast-steel brackets bolted to the lower valve-chest covers.

The *throttle valve*, 15 inches diameter, balanced piston head, is fitted with a by-pass, its weight and thrust being taken on ball-bearing rings fitted above and below the yoke of the vertical throttle-valve stem.

The slotted arms of reverse shafts, or "gag links," give independent cut-off for each cylinder, which may be varied from .56 to .80 of stroke for H.P.; .53 to .76 for I.P., and .50 to .78 for L.P.

The *pistons and followers* are of cast steel; each piston has two packing rings of cast iron 1 inch thick and 1¼ inches wide on wearing surface, cut obliquely, tongued, limited in play, and set out by steel springs. The *piston rods* are made hollow (8½ inches outside diameter and 5 inches and 4½ inches inside diameter), of high-grade machinery forgings; the lower end of each rod is

secured to a forged-steel crosshead by a steel nut. The *connecting rods* are of high-grade forgings, twice the stroke (8 feet) in length, and 7¼ inches in diameter at neck, crosshead end, and 8¾ inches diameter at neck, crank-pin end; all have an axial hole through them 2 inches in diameter. The crosshead end is forked to span the crosshead, faced off and fitted with two bearings for crosshead brasses and bolts. The *eccentrics* are made in two parts, the larger part of cast iron and the smaller part of forged steel, tongued, grooved, fitted together and secured by two steel bolts; each backing eccentric is secured to the shaft by a key, and each go-ahead eccentric is secured to shaft by a key with adjusting pieces between key and eccentric. The *straps* for these eccentrics are of composition with flanges to fit over the rabbets of the eccentrics and squared-off lugs for bolting to the T-head of the forged-steel eccentric rods; each rod is 8 feet 3 inches long between centers. Eccentric straps, crank-pin brasses, crosshead brasses, crosshead slippers, main bearing caps and bottom brasses, and the twelve cast-steel horseshoes of each thrust are fitted with anti-friction metal, Bureau of Steam Engineering formula.

There is one section of *crank shaft* for each cylinder, of solid forged steel with coupling disk or flange forged on each end; these shafts have axial holes through journals and crank pins.

The *propellers* are of manganese-bronze, the starboard one right-handed and the port one left-handed. Blades, bosses, caps and covers are smoothed all over and tinned. In the shop the propellers were swung on a mandrel between centers and accurately balanced by removing excess of metal on the heavier blades. The boss is secured to the shaft by a fore-and-aft key and a nut screwed on the end of the shaft, threaded left-hand for starboard and right-hand for port. Each blade is secured to the boss by nine tap bolts 4 inches in diameter and 7⅞ inches long under head, made of rolled manganese-bronze. Slotted holes allow of adjustment of pitch of blades as noted below:

Number blades	2
Diameter of propeller, feet	18
boss, feet and inches	4–6
Length of boss, feet and inches	3–7

Pitch, cast, feet	22
adjustable, feet and inches	20–6 to 23–6
Expanded area, total (one screw), square feet	92
Projected area, square feet	74
Pitch as set for trial, feet	22

The *steam jackets* receive steam as follows: live steam passes through a reducing valve to the top head of the H.P. cylinder, and by an outside pipe to the barrel and bottom head; thence through a second reducing valve to the top head of the I.P. cylinder, and by an outside pipe to the barrel and bottom head; thence through a third reducing valve in a similar way to both L.P. top heads and to the barrels and bottom heads; these L.P. bottom heads drain through valves under the cylinder to traps.

The *feed-water heaters*, one for each engine room, are vertical and cylindrical; steam from the auxiliary exhaust pipe is admitted at middle of length (steam around the tubes) and a large drain leads to the condenser; the feed can be forced through the tubes of heaters by the hot-well pump and thence to overhead pipe, 8-inch diameter, supplying suctions of main feed pumps in fire-rooms, or it can be by-passed to these suction pipes direct. All main feed pumps receive their feed water from this 8-inch overhead pipe, which extends along the middle-line bulkhead above the tops of main feed pumps and thus gives them a good head of water in case, of course, the hot-well pump is delivering properly. To maintain and regulate the pressure in the auxiliary exhaust pipe, when using feed heaters, there are spring relief valves opening towards the condensers in the auxiliary exhaust pipes at each connection with the condensers.

TABLE OF DIMENSIONS.

Main steam pipe (lap-welded steel), diameter, inches	14¼
area of cross section, square inches	173.782
Cylinders for each engine	4
diameter, H.P., inches	38½
I.P., inches	63½
F.L.P. (one), inches	74
A.L.P. (one), inches	74
stroke, feet	4

Valves, chest linings, H.P. (one), inside diameter, inches	26
I.P. (two), inside diameter, inches	26
L.P. (four), inside diameter, inches	28
Valve stems, H.P. (one), diameter, lower end, inches	3½
through valve, inches	2
at balance pistons, inches	1¾
I.P. (two), diameter, lower end, inches	3½
through valve, inches	2
at balance pistons, inches	1¾
L.P. (four), diameter, lower end, inches	3½
through valve, inches	2
at balance pistons, inches	1¾
Balance-piston cylinders, diameter, inches, H.P.	6
I.P	6
L.P	10
Piston rods, diameter, inches	8½
axial hole, H.P. and I.P., diameter, inches	4½
L.P., diameter, inches	5
Cylinder walls, H.P., inches	2½
I.P., inches	2
L.P., inches	1¾
liners, H.P., inches	1¾
I.P., inches	1¾
L.P., inches	1½
Jacket space, inch	¾
Valve-chest liners, thickness, inches	1⅜
Cylinder relief valves, two each cylinder, diameter, inches	4½
Connecting rod, length, center to center (in strokes, 2) feet	8
diameter, top end, H.P. and I.P., inches	7½
L.P. (both), inches	6½
bottom end, H.P. and I.P., inches	8½
L.P. (both), inches	7½
axial hole, inches	2
Crosshead slipper, ahead surface, L.P., square inches	612
H.P. and I.P., square inches	918
backing surface, L.P., square inches	442
H.P. and I.P., square inches	646
pin, diameter, H.P. and I.P., inches	11½
L.P. (two), (each), inches	9½
length, H.P. and I.P., inches	12⅛
L.P. (two), (each), inches	10⅛
Crank shaft, number of sections (one engine)	4
length (four sections), feet and inches	38– 2
diameter, inches	18½
axial hole, diameter, inches	10
coupling discs, diameter, inches	32½

Crank shaft, coupling discs, thickness, inches	4½
bolts in one flange (eight), diameter, inches,	3¼
pin, diameter, inches	20
length, H.P. and I.P., inches	23
L.P. (two), (each), inches	15½
axial hole, diameter, inches	12
Crank webs, width, inches	21½
thickness, inches	11½
Thrust shaft, length, feet and inches	17– 9
diameter, inches	17½ and 18½
axial hole, diameter, inches	10
collars, one shaft	13
diameter, inches	28
thickness, inches	2
space between, inches	4½
total surface, two engines, square inches	5,616
Line shaft, number of sections (one engine)	2
length (two sections), feet and inches	29– 6½
diameter, inches	17½
axial hole, diameter, inches	10½
coupling discs, diameter, inches	32½
Stern-tube shaft, length, feet and inches	32– 11
diameter, inches	18½
axial hole, diameter, inches	10½
Propeller shaft, length, feet and inches	45– 1
diameter, inches	18½
axial hole, inches	10½
Shafting, total (one engine), length, feet and inches	163– 4½
Reversing engine, steam cylinder, diameter, inches	16
oil cylinder, diameter, inches	10
stroke, inches	23
Turning engine, steam cylinders (two), diameter, inches	8
stroke, inches	8

There is one *main condenser* in each engine room, outboard side, located well up under the protective deck; it is cylindrical in shape, with an inside diameter of shell of 7 feet. This shell is of boiler plate steel $\frac{5}{16}$-inch thick, with double butt joints and circumferential T-bar stiffeners: an angle iron riveted around each end forms flanges for securing the water chests; these latter are of cast composition $\frac{3}{4}$-inch thick, and each has six 10-inch manholes fitted with composition covers and zincs; each water chest has nine stay bolts connecting to its tube sheet. The tube sheets are stayed to each other by six rods $\frac{3}{8}$-inch diame-

ter, taking the place of a similar number of tubes. (This is not contemplated in the original design.) The tube sheets are made of rolled Muntz metal 1 inch thick; there are 5,662 seamless-drawn tubes (composition 70 copper, 29 zinc, 1 tin) $\frac{5}{8}$-inch outside diameter, No. 18, B.W.G., 15 feet 6 inches long between tube sheets, spaced $1\frac{5}{16}$ inch between centers. Cotton tape packing was used in packing these condensers, set up by Star condenser packing tool, and held in place by screw glands having 18 threads per inch. The cooling surface for each condenser is 14,359 square feet, measured on outside of tubes.

VALVE DATA (*COLORADO*).

Total I.H.P.....23,000 for 2 engines (designed.)
Type and No. of engines.....Vertical, inverted, triple-expansion, twin-screw.
Diameter of cylinders and stroke.....38½″, 63½″, (2) 74″ × 48″ stroke.
Valve gear.....Stephenson link, double bar, direct connected, open rods.
Connecting rod.....96″, 4 cranks.

	H.P.		M.P.		L.P.	
Eccentricity, inches	5¼		5¼		5¼	
Travel of valve, inches	10¼		10¼		10¼	
Number of valves	1 piston.		2 piston.		2 piston.	
Diameter of valves, inches	26		26		28	
Side of valve on which steam is taken	Inside.		Outside.		Outside.	
	Top.	*Bot.*	*Top.*	*Bot.*	*Top.*	*Bot.*
Width of port, inches	3⅝	3⅝	3 1/16	3 1/16	4	4
Steam lap, inches	2¼ + 1/64	1¼	2 3/32	1 29/32	2 1/8	1 7/32
Exhaust lap, inches	−⅝	−⅛	−⅝	−⅛	None.	1 1/32
Angular advance, degrees	34¼		36		36	
Steam lead, angular, degrees	8¼	14¼	8¼	14¼	8¼	15¼
linear, inches	1 1/16	1 7/8	1 1/16	1 7/8	1 1/16	1½
Cut-off, inches (f, full)	38 13/32	36 1/16	37 9/16	34 1/16	37 9/16	35 1/16 f.
decimal of stroke	.8	.756	.775	.725	.775	.73
Exhaust release, decimal of stroke	.0833	.114	.092	.126	.074	.039
lead, inches } s, scant	3 5/16	3 1/16	3 1/32	3 7/32	3 3/32	1 1/16 s.
Compression, inches } f, full	4s.	2 5/16	4⅛	3 5/16	5⅛ f.	7¼
decimal of stroke	.083	.061	.094	.069	.118	.151
Steam opening, inches	2 13/32	3¼	2 7/32	3 1/32	2 7/32	3 1/32
Exhaust opening, inches	3⅜	3⅜	3 1/16	3 1/16	4	4
Velocity of steam, feet per second: piston speed, 960 feet per minute	100.79	89.12	143.9	122.3	177.4	148.1
exhaust, ft. per second: piston speed, 960 feet per minute	89.12	89.12	111	111	126.1	126.1
	1 valve.		2 valves.		2 valves.	
Length of port, clear opening, ins.	61.93		2×61.93 =123.86		2×68.21 =136.42	

The condenser tubes are supported at two intermediate points by ferrules $\frac{3}{4}$-inch long, inserted in supporting plates, the ferrules and plates being made of the same material as the tubes. Baffle plates of steel are fitted to direct the steam over all the tubes. There is one hand-hole, 7 inches $\times$ $3\frac{3}{4}$ inches, in the bottom of each tube sheet. The water chests are fitted with rolled zinc plates. The usual fittings are bolted to the condenser in the usual manner.

The *main air pumps* are of the Blake type, as are all other steam-driven pumps in the ship except auxiliary condenser pump in engine room; they are double, vertical, single-acting, with two inverted steam cylinders 14 inches in diameter and common stroke of 18 inches. The air-pump buckets are of composition and the air-pump valves are made up of three flat disks of rolled manganese-bronze $\frac{1}{32}$-inch thick, held in place by a spiral spring and guard; the suction pipe is 13 inches in diameter, the discharge pipe 11 inches in diameter. The discharge pipe leads to the filter tank, which is simply the upper portion of the feed tank divided into compartments for filtering material, "*loofah*" being used. The main air pumps are located just abaft the condensers and the main circulating pumps just forward of the condensers.

The *main circulating pumps* (two) are double inlet, centrifugal—diameter of inlet, 21 inches; diameter of outlet, 21 inches; diameter of pump runner, 4 feet 6 inches—driven by an independent compound engine. The H.P. cylinder is 11 inches, and the L.P. cylinder is 19 inches diameter $\times$ 12 inches stroke. A test of these pumps just previous to the official trial trip gave for each pump the following results: At 245 revolutions per minute one engine room compartment was cleared of 18 inches of water in 30 seconds, an estimated capacity of 18,000 gallons per minute. The specifications called for 15,000 gallons per minute. The suction valves to these pumps (see main drain and bilge injection) are fitted with pivoted horizontal, ratchet-toothed levers, so arranged that only one of the three valves can be opened at any one time. Safety sluice valves are fitted for sea injection and outboard delivery, being stowed in racks near the respective valves.

The *feed tanks* are located one in each engine room, outboard and

aft, and extend in height from the inner skin to the under side of protective deck, and have a total capacity of 10,660 gallons of fresh water. They are cross connected, fitted with doors at top, manholes at bottom, overflow and vapor pipe, glass gauges, and float-lever valve to suction outlet.

A horizontal, light-service, *hotwell pump*—12 inches × 16 inches × 16 inches—is located under each main condenser. It has a suction manifold connecting to feed tanks, main condenser channel way, reserve double-bottom tank, and connections for water boat—one suction from each bow and one from each quarter; its discharge manifold has connections to the reserve feed tanks and the main feed line suction through a cartridge-shaped grease extractor, using toweling or burlap. This grease extractor may also be by-passed.

On the forward 'thwartship bulkhead of each engine room is a vertical *fire and bilge pump*, single-cylinder type, 12 inches × 10 inches × 12 inches, drawing from the sea, the main and auxiliary drains, the engine-room bilge and the crank pit. There is also a shaft bilge pump worked by a crank pin on the forward end of the main crank shaft, drawing from the engine-room bilges and crank pits in its own compartment.

In the after end of each engine room, near the middle-line bulkhead, there is a vertical *auxiliary condenser*, with a cooling surface of 795 square feet, in which the steam passes through the tubes; it has bolted to it a vertical, single-acting air pump and a double-inlet, centrifugal circulating pump, driven from the horizontal shaft of an inverted single-cylinder engine. Size of steam cylinder, 6¼ inches; air-pump cylinder, 7½ inches; stroke, 7 inches diameter of pump runner, 4 feet 6 inches.

The *reversing engine* for each main engine consists of a steam cylinder whose diameter is 16 inches, and an oil-controlling cylinder, diameter, 10 inches; stroke, 23 inches; the common piston rod of both cylinders acting directly on two arms keyed to the reverse shaft. The steam valve is of the piston type, the admission of steam being regulated by a floating lever in the usual way. There is a hand-pump connection for reversing by hand.

The *turning engine and gear* consists of a double-cylinder

engine, cylinders 8 inches × 8 inches, driving a worm gearing and a second worm which meshes with a worm wheel fitted on a crank-shaft coupling. A ratchet is fitted for turning the main engines by hand.

A *dynamo condenser*, located in the dynamo room, is used exclusively for the dynamos. It has a horizontal, combined air and circulating pump under it, 12 inches × 14 inches × 14 inches × 12 inches. This dynamo condenser has 1,200 feet of cooling surface.

The forced-draft blowers—Sturtevant type—are located on the berth-deck enclosures, and furnish forced draft on the closed fireroom system. There are sixteen of these blowers, running at about 500 revolutions per minute to maintain 1½ inches to 2½ inches of air pressure; each having two simple cylinders, 5 inches diameter and 4 inches stroke, and a common valve actuated by one eccentric.

Oil tanks, having a total capacity of 3,000 gallons of oil, are located in the after ends of the engine rooms; small steam pumps, one in each engine room, having fine-mesh Macomb strainers, draw oil from these main tanks and deliver it to cylindrical distributing tanks, one for each engine room, located on the middle-line bulkhead under the protective deck. Pipes from these latter tanks, whose capacity is 25 gallons each, lead to all the oil boxes on the main engines.

Opening out of the forward part of each engine room at the level of the first gallery is the *workshop*, an archway in the middle-line bulkhead connecting the starboard side of this workshop to the port side of same, entrance being had from either engine room. This shop has its shafting driven by an electric motor 15-H.P., and the following tools are installed: one screw-cutting back-geared gap lathe, swings 30 inches over ways and takes 10 feet between centers; one 14-inch screw-cutting back-geared lathe, takes 4 feet between centers; one column shaping machine, 15-inch stroke, 26-inch traverse; one back-geared drilling machine, drills 1½ inches, 18 inches from edge of work; one 16-inch sensitive drill; one No. 1 universal milling machine; one combined hand punch and shears, cuts ¾-inch round iron,

shears ⅝-inch plate, punches ⅝-inch holes in a ⅝-inch plate; one emery grinder, two 12-inch wheels; one 30-inch grindstone, and six bench vises.

There is no *water-service pump*, water for bearings being taken from the main circulating-pump discharge pipe just before it joins the condenser.

There are four *evaporators*—Bureau of Steam Engineering type—and three *distillers*, having straight tubes. The distillers are located in the hatch over the evaporator room. The evaporators have a combined capacity of 23,000 gallons of potable water in 24 hours, and the distillers have a rated capacity of 10,000 gallons in 24 hours. Each evaporator has 290 square feet of tube-heating surface, and each distiller has 66 square feet of tube-cooling surface. The evaporators are arranged in pairs, two on the berth deck and two immediately over them on the gun deck; access from one set to the other is through grated hatch. The steam piping is arranged for "double effect." The following pumps are installed, all in the lower evaporator room: a horizontal distiller circulating pump—which is also the flushing pump—12 inches × 16 inches × 16 inches; a vertical evaporator feed pump, 4½ inches × 5 inches × 6 inches; a combined brine and fresh-water pump, 6-inch steam cylinder × 5-inch fresh-water cylinder × 4-inch brine cylinder × 6-inch stroke.

There is one double-cylinder reversible *ash-hoist engine* for each fire room—ten in all—bolted to the bulkheads at the gun-deck level.

The *coal bunkers* are twenty-eight in number, twelve above the protective deck and sixteen below this deck; the coal capacity is 1,827 tons at 43 cubic feet to the ton.

The *ice machine*, located forward of the casemate enclosure on the berth deck, has a per diem capacity equivalent to the cooling effect of three tons of ice, and is piped up to the cold-storage rooms (4), scuttle butts (2), and ice freezing tank. It is of the Allen dense-air type. All deck winches and cranes are driven by electric motors.

The *steering engine* is of the Williamson type, controlled by

wire-rope transmission from conning tower, pilot house and upper bridge.

The *ventilating blowers* for engine rooms are located amidships, between the engine-room hatches, on the gun deck; they are driven by electric motors, and furnish fresh air to all parts of the engine rooms by ducts of suitable size.

The principal *watertight doors* are all operated on the Long-Arm system by electric motors.

The *boilers* are thirty-two in number, placed in six watertight compartments, three compartments on each side of the middle-line bulkhead. The firerooms are roomy, the passages large, and the spaces about steam drums and uptakes ample for all necessary purposes. The boilers are installed in pairs, each boiler having one furnace and three furnace doors, to the casual observer a pair having the appearance of one boiler with six furnace doors. The boilers are of the Niclausse type as improved by the sub-contractors, the Sterling Company. One boiler of each pair has 14 elements, and the other boiler 13 elements, each element having 24 tubes 7 feet 5 inches long, exposed length, and 3¼ inches outside diameter.

The heating surface in a 14-element boiler is 2,221 square feet and in a 13-element boiler is 2,062 square feet, making a total heating surface of 68,537 square feet for all boilers. The grate surface in a 14-element boiler is 52 square feet and in a 13-element boiler is 48 square feet, making a total grate surface of 1,600 square feet for all boilers. Ratio of heating surface to grate surface 42¾ to 1. The boiler headers are of wrought-steel and the tubes are of seamless drawn-steel. The sides and back of boilers are plate steel lined with firebrick and tiles. The steam drums are 42 inches outside diameter and 8 feet 5 inches long.

The safety valves are set at 300 pounds.

The grate bars are of the contractors' shaking type, of cast iron, 6 feet 1¼ inches long. There are four smoke pipes each 93 feet in height, measured from the grate-bar level, each of 9 feet 4 inches diameter.

Each boiler has one twin safety valve 2½ inches diameter, a sentinel valve, one stop valve, one Klinger water gauge, one

ordinary water gauge, three try cocks, one bottom blow, one surface blow, one automatic (float controlled) main-feed double check valve, one auxiliary-feed double check valve, three horizontal, pivot, self-closing ash-pan doors; three horizontal, balanced furnace doors; three ash pans. The boiler stop valves can be closed (in case of a burst tube) by opening a small valve from the opposite fireroom; the safety valves may be raised by operating wheels at fireroom level or gun-deck level.

The *weights of boilers* are as follows: 13-element boiler (drums, tubes, headers, etc.; *i. e.* the bare boiler), 47,913 pounds; same for the 14-element boiler, 50,114 pounds; the weight of grate bars, bearing bars, casing, bridge walls, furnace fronts, etc., etc. (average of twelve boilers, half of each size), for one boiler, is 6,198 pounds. The weight of water in one boiler, one-half glass, 13-element, 3.94 tons; same for one boiler, 14-element, 4.22 tons. General average weight, one boiler (empty), 27.6 tons; same for water in one boiler, 4 tons.

The boilers are fitted with dry pipes, zincs, and baffles for directing the products of combustion. The baffles consist of common iron pipes $1\frac{3}{4}$ inches diameter, laid on top of the tubes. There are fifty-eight of these baffled tubes in each boiler, filling the spandrels of the tubes at sides; middle, four rows down; and sides, half way down, inclined towards middle of boilers.

There are four *main feed pumps* in the starboard firerooms, and four *auxiliary feed, fire and bilge pumps* in the port firerooms all secured to the middle-line bulkhead and of same size and pattern, namely: vertical, duplex, double-acting, outside-packed plunger, with inverted steam cylinders; the steam cylinders are 12 inches diameter, water plungers $7\frac{5}{8}$ inches diameter, and stroke 12 inches. Of the three watertight compartments containing the starboard boilers, the after one has two main feed pumps, and the other compartments one each; a similar arrangement holds for the auxiliary feed, fire and bilge pumps of the port fireroom compartments. Any one of these eight pumps will feed any and all boilers. The four main feed pumps draw only from the overhead main supply pipe, which is kept under a slight pressure

from the hotwell pumps discharge, as noted before; the safety-feed relief valve by-passes the main-feed discharge water whenever the automatic lever, by means of its float in steam drum, closes the cock to main-feed check valve.

The *main steam piping* is arranged symmetrically in two systems, one for each side of the ship, each system being independent except for a cross connecting pipe near the main engines. The leads from the forward boilers aft to the engine room are straight, without curves for expansion, but slip joints are placed wherever needed and brackets secured to the under side of protective deck allow for expansion and hold the pipe firmly between fixed points. The size of the main steam pipe in the forward compartment, where six boilers on one side lead into it, is $9\frac{1}{8}$ inches; when four more boilers connect to it from the middle compartment the size is increased to $11\frac{1}{4}$ inches; and when six more boilers join it from the after watertight compartment the size is increased to $14\frac{1}{8}$ inches.

The auxiliary steam-pipe system parallels the main system but extends forward and has a cross connecting pipe before passing to the dynamo rooms; it also has a cross connecting pipe in the engine rooms and connects to the main system. All the flanges in these two systems are much heavier than usual, with bolts spaced nearer together, and with no male and female joints; the gaskets are of corrugated copper. Since these joints and pipes were first tested there have been no leaks of any kind, which is a practical comment in favor of the workmanship and strength. An excess of weight will doubtless be shown over other schedules, but certainly it is weight well expended.

OFFICIAL PRELIMINARY SPEED TRIAL.

The *speed trial* took place over the Cape Ann course, 44 knots long, on October 24, 1904. The sea was smooth and weather conditions good. The machinery worked very satisfactorily indeed; there were no hot bearings and the boilers made all the steam the engines could use under the conditions imposed by the Navy Department, limiting the steam pressure in the H.P. receiver to 250 pounds per square inch. The safety valves were

blowing off steam during practically the entire run, they being set at 300 pounds pressure. The steadiness and lack of vibration of the engine frames was very noticeable when it is considered that at times the I.H.P. of the *main engines alone* was in the vicinity of 28,000. This style of engine housing (inverted Y cast-steel frames inboard, and forged-steel columns outboard, all thoroughly tied by athwartship as well as by fore-and-aft braces) must be considered an excellent one. Live steam was admitted to I.P. receivers during all the run and into the L.P. receivers during most of the time.

The boilers were fired at regular intervals, boys being detailed as time keepers. The time interval was one minute for opening doors, the same door being opened for firing or hoeing (no slicing) every three minutes; the thickness of the fires was from five to eight inches. Pocahontas coal was used.

Speed.—The average speed during the entire run, corrected for tide, was 22.224 knots.

SYNOPSIS OF STEAM LOG.

Performance:	
Steam pressure at boilers (gauge), pounds	296.2
H.P. steam chest, S. engine (gauge), lbs.	250
P. engine (gauge), lbs.	248
1st receiver, S. engine, absolute, pounds	118
P. engine, absolute, pounds	114
2d receiver, S. engine, absolute, pounds	39
P. engine, absolute, pounds	36.4
Vacuum in condensers, in inches of mercury.....P., 21.3; S.,	21.25
Mean effective pressures in cylinders in pounds, per square inch:	
Main engines, starboard, H.P.	107.44
I.P.	52.1
F.L.P.	17.57
A.L.P.	17.74
port, H.P.	106.94
I.P.	52.344
F.L.P.	15.32
A.L.P.	14.84
Mean pressure, in pounds per square inch on L.P. piston, equivalent to aggregate M.E.P. on all pistons, starboard	51.07
Mean pressure, in pounds per square inch on L.P. piston, equivalent to aggregate M.E.P. on all pistons, port	48.52

Revolutions per minute:	
Main engines.....starboard, 126.2; port,	127.39
Pumps, air.....starboard, 34.5; port,	31
circulating.....starboard, 189; port,	190
main feed, double strokes per minute.....	36.85
auxiliary, fire and bilge.....	51.1
Speed of ship in knots per hour.....	22.244
Slip of propeller in per cent. of its own speed, based on mean pitch.....starboard, 18.81; port,	19.57
Air pressure in firerooms, in inches of water.....	1.49
Indicated horsepower:	
Main engines, starboard, H.P.....	3,732.7
I.P.....	5,003
F.I.P.....	2,296.55
A.I.P.....	2,318.2
total.....	13,350.45
port, H.P.....	3,750.4
I.P.....	5,073.8
F.I.P.....	2,021.3
A.I.P.....	1,958
total.....	12,803.5
Air pump.....starboard engine, 21.64; port engine,	21.90
Circulating pump.....starboard engine, 97.38; port engine,	93.51
Feed pumps, main.....	391.6
auxiliary.....	56.6
Auxiliary condenser air pumps.....	Not in use.
Hotwell pumps (estimated).....	9.10
Distiller circulating pump (estimated).....	2.71
Dynamo auxiliary condenser circulating pumps.....	4
Ventilating engines.....for ship, electric; for engine rooms, electric.	
Blower engines for forced draft in firerooms.....	437.4
Dynamo engines.....	72.5
Collective of both main engines.....	26,153.95
main engines, air, circulating and feed pumps.....	26,836.58
and auxiliary engines in operation during trial..	27,373.83
all machinery during trial, per square foot of G. S.....	17.11
H. S.....	.3994
Main engines, air, circulating and feed pumps, per square foot of G. S.....	16.769
Main engines, air, circulating and feed pumps, per square foot of H. S.....	.3918
Coal—kind and quality.....Pocahontas, run of mine.	
pounds per hour.....Not measured.	
Cooling surface, square feet per I.H.P.....	1.049
Heating surface, square feet per I.H.P.....	2.503

NOTES.

For the trial of the *Colorado* the Cramps took on board for the Engineer Department alone the following number of men, who stood watch in *six-hour* watches:

Engine-room watch engineers,	4
Oilers,	28
Engine-room boys (messengers),	4
Engine-room machinists,	4
Senior fireroom engineers,	2
Fireroom engineers,	12
Water tenders,	20
Machinists,	12
Fireroom boys (held watches, called time interval in firing),	21
Firemen,	64
Trimmers,	64
Firemen and trimmers (for spares and ashes),	25
Blower men,	10
Storekeepers,	2
Boiler makers,	2
Evaporator engineers,	2
Ice machine engineers,	2
	278

The diameter of main steam pipe is 14⅞ inches, the original design being 13 inches only for 23,000 estimated H.P. The contractors made this change to obtain the required engine power (over 26,000 H.P. as shown on the trial); but the synopsis of steam log shows a drop in pressure from boilers to H.P. steam chest which cannot be attributed wholly to inadequate steam-pipe area. Very possibly a large part of this drop in pressure is accounted for by the fact that, *all the junctions are right angled*, both from boilers to auxiliary, and from auxiliary to main steam pipes.

From the time the vessel left the shipyard for New York to be docked, thence to Boston, thence back to Philadelphia—eleven days—there was used 75 barrels of lard oil.

Photograph of *Colorado* made for the Society by Mr. John W. Dawson, Philadelphia.

THE POWER PLANT OF THE UNIVERSAL EXPOSITION AT ST. LOUIS.

By C. K. Mallory, U. S. Navy, Member.

The Power Plant of the Louisiana Purchase Exposition is one of more than ordinary interest to the engineer, being composed of a large number of units of different types and representing the latest practice in several foreign countries as well as in the United States.

The plant proper consists of twenty-two steam engines, a gas engine, and a tangentical water wheel, all direct connected to electric generators; the normal horsepower developed amounts to about 40,000 from which an electrical output of 23,000 kilowatts is obtained, the remainder being utilized for the operation of fire pumps and the various engine and boiler auxiliaries.

Steam is supplied by fifty-two boilers of various makes but all of the water-tube type. With the exception of four 3,000-horsepower engines, all of the units of the plant, with their boilers and auxiliaries, were obtained as exhibits, being entered in competition for awards; the number of firms represented being over one hundred.

To meet the variety of requirements for an exposition it was found advisable to divide the plant into several systems, of which the most extensive is the *General Lighting and Power System.* From this system is obtained the current for decorative lighting of buildings and the operation of cascade pump motors. The normal output is 16,000 kilowatts with a 6,600-volt, 25-cycle, 3-phase current.

Next in importance is the *Intramural Railway System* used for operating the cars throughout the exposition grounds. The system has an output of 3,500 kilowatts with a 550-volt direct current.

The *Arc Lighting System* consists of four units with a capacity of 2,450 kilowatts, the currents being respectively 2,400 volts, 3-phase, 50 cycles; 2,300 volts, 3-phase, 50 cycles; and 2,300 volts, 1 and 2-phase, 50 cycles.

For various uses, such as the operation of motors in exhibits, elevators, coal conveying machinery and charging storage batteries, there is a *direct-current system* of 250 and 110 volts, also a *multiple-voltage system* for the operation of machine tools by direct-connected variable-speed motors.

The largest individual unit forms part of the *general lighting and power system.* It consists of a 5,000-horsepower Allis-Chalmers vertical and horizontal Corliss compound engine, direct connected to a Bullock 3,500-kilowatt generator.

The engine is of the Reynolds-Corliss type, similar to those used for the Manhattan Railway in New York, with horizontal high-pressure cylinder and vertical low-pressure cylinder, both connecting rods working on the same overhanging crank pin. The number of working parts is still further reduced by operating the high-pressure and low-pressure valves from the same eccentrics, there being one eccentric for both sets of steam valves and one for both sets of exhaust valves.

The governor, which is of the weighted type, regulates the cut-off in both cylinders; it is fitted into a movable weight, by means of which a variation of two-and-a-half revolutions on either side of the normal may be obtained; a second synchronizing weight, moved by an electric motor controlled from the switchboard, is fitted for use when running in parallel with other machines.

The cylinder diameters are 44 inches and 94 inches; stroke, 60 inches; and speed, 75 revolutions per minute.

The flywheel has a weight of 300,000 pounds, is 25 feet in diameter, being built up of ten sections; the total engine weight is 720 tons.

The generator is the Bullock Standard, revolving-field type, the windings of both armature and field being of copper strips. The exciting current for the field is furnished by an Ide 300-horse-

power tandem, compound steam engine, direct-connected to a Bullock 200-kw., 250 volts, direct-current generator; the current from this machine, not required for excitation, is passed through a Bullock multiple voltage, balance set, and made available for use with variable-speed motors.

For the exhaust of the Allis-Chalmers engine, the Alberger Condenser Company furnishes a barometric tube condensing outfit, having a capacity of 120,000 pounds of steam per hour. The condenser consists essentially of a condensing chamber placed about 40 feet above the hot well, to which it is connected by a 20-inch tail pipe; the exhaust steam and injection water enter this chamber on opposite sides, near the top, the latter being admitted in the form of a spray through an automatically-controlled conical valve. The exhaust steam and injection water first meet near the top of the chamber and again near the bottom, thus causing the water to leave the condenser at the highest possible temperature; it passes through the tail pipe to the hot well, and is carried away by gravity.

The air and non-condensable vapors are removed by means of a dry vacuum pump which takes its suction from the top of the condensing chamber. A small part of the injection water is admitted to the space in the upper part of the chamber and serves to reduce the temperature of these vapors, making the use of an air cooler on suction pipe unnecessary.

The dry vacuum and circulating pumps are driven by a vertical Corliss engine with automatic cut-off governor. The vacuum pump is driven by a crank, and the circulating pump, which is of rotary type, is connected directly to the engine crank shaft.

The following are the principal dimensions of this installation:

Diameter condensing chamber, inches	58
Length condensing chamber, parallel body, inches	78
Diameter exhaust opening, inches	36
injection inlet, inches	16
vacuum pump suction, inches	6
tail pipe, inches	20
Pump engine, steam cylinder, inches	16 × 24
vacuum cylinder, inches	24 × 24
Normal capacity of circulating pump, g. p. m	5,000

Two steam turbines are included in the *general lighting and power system*, one of the Curtis type, exhibited by the General Electric Company; the other of the Hamilton-Holzwarth type, exhibited by the Hooven, Owens, Rentschler Company. The Curtis machine is of the four-stage vertical type, with a normal output of 2,000 kilowatts when operating at 750 revolutions per minute.

The revolving disc of each stage is fitted with two sets of vanes, a set of stationary vanes being placed between them. The steam, after expansion in the admission nozzles, passes the first set of revolving vanes, the pressure remaining constant with a decrease of velocity; it then enters the stationary set, through which it passes without change of either pressure or velocity, passing thence to the second revolving set, where the action is the same as in first. It will be noted that in the above process, which completes the first stage, the steam has passed two revolving and one stationary set of vanes, its pressure remaining the same as at outlet of admission nozzles but its velocity having been decreased.

The next process is to pass the steam through a set of stationary vanes or nozzles in which it is permitted to expand, producing a decrease in pressure and an increase in velocity, after which the action described for the first stage is repeated in the second and other succeeding stages

The condenser rests upon the main foundation, being located immediately below the turbine, for which it forms a base.

The weight of the revolving parts, amounting to about 50,000 pounds, is taken by a step bearing at the bottom of the vertical shaft, to which oil is supplied at a pressure of about 450 pounds per square inch by a special pump.

Speed regulation is accomplished by the use of a spring-loaded centrifugal governor on the upper end of shaft; the governor operates electrically-controlled throttle or admission valves, of which there are two sets of ten each, located on opposite sides of the turbine.

The generator is the General Electric Company's four-pole revolving-field type, with a normal output of 2,000 kw., a momentary overload capacity of 100 per cent., and of 50 per cent. overload capacity for a period of two hours.

Current for field excitation is obtained from a direct-current horizontal turbine, set with a capacity of 25 kw., operating at 3,600 revolutions per minute, with a steam pressure of about 125 pounds per square inch.

The condenser is the Worthington surface type, rectangular in shape, containing 8,000 square feet of cooling surface.

Motor-driven centrifugal pumps are used for supplying injection water and to free the condenser of condensed steam.

The dry vacuum pump, which is also driven by an electric motor, takes its suction from near the bottom of the condenser; an air cooler, through which the injection water passes, is located in this suction pipe; the circulating water enters and also leaves the condenser at the top.

The Hamilton-Holzwarth turbine is of the horizontal type, built in two parts, high pressure and low pressure, both operating the same shaft to which the generator is direct connected. There are flexible shaft couplings between the high-pressure and low-pressure turbines and also between the low-pressure turbine and the generator.

The unit has a normal output of 1,000 kw. when operating at 1,500 revolutions per minute.

As the turbine works by impact only, the fitting of balance pistons is not necessary.

The revolving vanes are situated on the circumferences of discs which are keyed to the shaft, while the stationary vanes are on discs whose circumferences are set into the casting which forms the turbine casing; at the center there is a circular opening of slightly larger diameter than that of the shaft.

The steam first passes a set of stationary vanes in which it is permitted to expand, giving a decreased pressure and increased velocity, then it passes through a set of revolving vanes where the pressure remains constant but velocity decreases; this is repeated for each pair of vanes in the high-pressure turbine, after which the steam is led through a receiver pipe to the low-pressure, where the same action again takes place.

Speed regulation is obtained by the use of a spring-and-weight governor of the throttling type. The governor controls the main

admission valve, which alone operates under ordinary circumstances; but should there be a sudden overload, the regulating mechanism automatically opens a by-pass valve admitting live steam to the low-pressure turbine. Before being admitted, however, the steam passes through a nozzle of the DeLaval type, giving it an increased velocity and reducing its pressure to that of the exhaust from the high pressure.

The generator is of Bullock revolving field type. A Bullock direct-current generator is mounted on the main shaft to furnish current for field excitation.

The condenser equipment is exhibited by the Stilwell-Bierce and Smith-Vaile Company. It consists of a surface condenser with 7,000 square feet of cooling surface, a cross-compound circulating pump, a two-stage, straight-line dry vacuum pump, and a vertical wet vacuum pump.

In addition to this turbine, the Hooven, Owens, Rentschler Company furnishes for the same system a 2,250-horsepower, vertical, cross-compound Corliss steam engine, direct connected to a National Electric 1,500-kw. alternator. The cylinder diameters are 34 inches and 68 inches, with a 54-inch stroke; the engine operates at a speed of 83 revolutions per minute. A reheater is placed between the high-pressure and low-pressure cylinders.

The condensing equipment, furnished by the Stilwell-Bierce and Smith-Vaile Company, consists of a surface condenser, with 4,000 square feet of cooling surface, a single vacuum pump, and compound, duplex, circulating pump.

The other units composing this system are four Westinghouse vertical, cross-compound Corliss engines of 3,000 horsepower each, driving two Westinghouse and two General Electric 2,000-kw. alternators. The cylinder diameters are 38 inches and 74 inches; stroke, 54 inches, and revolutions per minute, 85. The fly wheel is 23 feet in diameter and weighs about 170,000 pounds.

The valve gear is of the releasing type with separate eccentrics for steam and exhaust valves; an enclosed centrifugal governor controlling the steam valves of both cylinders is fitted; there are also automatic engine stops of the Monarch type.

The current for exciting the fields of the four generators is ob-

tained from three exciter sets consisting of 12-inch and 20-inch × 12-inch Westinghouse automatic compound engines, each direct connected to an 80-kw., 125-volt, direct-current generator.

The exhaust from all four engines is taken care of by two Worthington 40-inch barometric tube condensers; three Worthington dry vacuum pumps are used in connection with these condensers, two 10 inches × 22 inches × 18 inches, horizontal type, and one 8 inches × 16 inches × 12 inches, vertical type; air coolers are installed in the vacuum-pump suction lines.

For handling the circulating water, three Worthington 24-inch centrifugal circulating pumps, each with a capacity of 18,000 gallons per minute, are installed; one of these pumps delivers water to the condensers, a second pumps the return water into the cooling towers, while the third is held in reserve, and can be used for either of these purposes. The circulating water from these condensers is not permitted to enter the lagoons, as in the case of other installations. but is passed through four brick cooling towers located just outside the Steam, Gas, and Fuel Building, and is then returned to the condensers. Air is forced through these cooling towers by sixteen 120-inch disc fans, all driven by a Westinghouse 18-inch and 30-inch × 16-inch compound engine.

Seven units make up the *Intramural Railway System.* For each of these the Crocker-Wheeler Company furnishes a 550-volt direct-connected generator of the railway type. The largest unit of the group is a Buckeye 1,400-horsepower, horizontal, cross-compound engine, direct connected to a generator with a normal output of 900 kilowatts. The cylinder diameters are 26½ inches and 50 inches; stroke, 48 inches; revolutions per minute, 100. The fly-wheel has a diameter of 15 feet and weighs 40,000 pounds, the total engine weight being 300,000 pounds.

The special features of this engine are its valve mechanism and governor. The former consists of a balanced cylindrical valve with riding cut-off. The governor is of the shaft-regulating type, and serves to vary the advance of the eccentric which operates the cut-off valve. The travel of the main valve is uniform, and the mechanism for the operation of both valves is so arranged

that the cut-off valve always ends its stroke at the same point on the main valve.

The second unit of this system consists of a Lane & Bodley 900-horsepower, horizontal, cross-compound Corliss engine, direct connected to a 600-kilowatt generator. The principal dimensions of engine are as follows: Cylinder diameters, 20 inches and 40 inches; stroke, 54 inches; revolutions per minute, 85; fly-wheel diameter, 18 feet; weight of fly-wheel, 60,000 pounds; total estimated weight of engine, 200,000 pounds.

Separate eccentrics are used for the steam and exhaust valves with straight-line connections to the valves, the use of wrist plates being avoided; valve hooks operate by inertia and gravity, without springs; the governor is of the high-speed type, belt-driven from the main shaft, and controls the cut-off in both cylinders. There is also fitted an emergency governor which controls a steam-operated valve on the steam pipe.

The Murray Iron Works Company exhibits a single-cylinder 800-horsepower, horizontal engine, direct connected to a 500 kw. generator; the principal dimensions are as follows: cylinder diameter, 26 inches; stroke, 48 inches; revolutions per minute, 100; fly-wheel diameter, 16 feet; weight, 62,000 pounds; total engine weight, 145,000 pounds. The valves are operated by means of two eccentrics with wrist-plate motion. The governor is of the high-speed type with central stationary weight; an additional emergency governor controlling a weighted Corliss valve in the steam pipe is also fitted.

The Harrisburg Foundry and Machine Works makes an exhibit of more than ordinary interest, consisting of a 600-horsepower, horizontal, tandem, compound, four-valve, Fleming engine, direct connected to a 400-kw. generator. The cylinder diameters are 15 inches and 40½ inches; stroke, 26 inches, and revolutions per minute, 150; a re-heater is placed between the high-pressure and low-pressure cylinders.

The operation of valves, which are of the Corliss type, is accomplished by the use of three eccentrics and a very ingenious combination of bell-cranks and levers, the arrangement being such that an accelerated motion is given the valves at the points

of admission and cut off, without the use of detaching devices and dash pots. The steam valves of each cylinder are operated by one eccentric, while a single eccentric serves for the exhaust valves of both cylinders. The governor, which is of a balanced shaft type, regulates the travel of the high-pressure steam valves by moving the eccentric across the shaft; the eccentrics for the low-pressure steam valves and both exhaust valves are fixed.

It will be noted that the cylinder ratio is very high, amounting to about 1 to 7.33. Reports from a trial of a similar engine give a steam consumption of 12.66 pounds per indicated horsepower per hour at full rated load, and 12.33 pounds at about three-quarters load.

For use in this system, the Brown Corliss Engine Company furnishes two vertical cross-compound high-speed Corliss engines, with a normal rating of 750 horsepower each, the generators having an output of 500 kw.

The cylinder diameters are 18 inches and 36 inches; stroke, 36 inches; revolutions per minute, 135; flywheel diameter, 14 feet; weight of flywheel, 36,000 pounds.

The valve gear is of the releasing type operated by double eccentrics; the governor controls the cut-off in both the high pressure and the low pressure cylinders.

The most unique installation in connection with the operation of the Intramural Railway is that made by the Abner Doble Company, consisting of a 160-brake horsepower tangential water wheel, direct connected to a 100-kilowatt generator, operating at 700 revolutions per minute; the water is furnished at a pressure of 300 pounds per square inch by a Jeanesville Iron Works duplex, triple-expansion, condensing mining pump, having a capacity of 1,200 gallons per minute. Cylinder diameters, 11 inches, 17 inches and 30 inches × 10 inches; 36-inch stroke.

The water-wheel nozzle is of the needle regulating type, controlled by a Lombard governor. The amount of water furnished is measured by a Venturi meter fitted with a manometer and registering device. A surface condenser on the suction of the pump takes care of its exhaust steam.

The Alberger Condenser Company furnishes a condenser equipment for the Lane & Bodley, Harrisburg, and Murray engines; it consists of a counter-current surface condenser of the dry-vacuum type, having 5,000 square feet of cooling surface with a capacity of 50,000 pounds of steam per hour.

The exhaust from the engines enters the condenser at the bottom while the air and non-condensable vapors are removed by the dry-vacuum pump from the top; the condensed steam is removed from the bottom of the condenser by means of an automatic hotwell and a wet-vacuum pump; this water of condensation on its way to the hotwell comes in contact with the incoming steam from the engines, causing its temperature, upon leaving the condenser, to be raised practically to that of the exhaust steam.

The circulating water enters at the top and leaves the condenser at the bottom, thus reducing the tendency of foreign matter to settle in the shell and interfere with the circulation; the vapors, being removed from the top, are brought into contact with the upper and cooler sets of tubes before entering the pump, making the use of air coolers on the suction unnecessary.

The exhaust opening on condenser is 36 inches in diameter; circulating water inlet and outlet, each 14 inches; and air suction, 6 inches.

The circulating pump is of the double-suction centrifugal type, direct connected to a 12-inch × 12-inch-steam engine; the dry-vacuum pump is of the rotary type, driven by an 8-inch × 18-inch × 24-inch horizontal Corliss engine, fitted with an automatic governor.

The other engines of this system exhaust into a Wheeler condenser of the Admiralty type, with 4,500 square feet of cooling surface, operated upon the wet-vacuum system.

The circulating water enters at the bottom and is removed from the top; the exhaust steam is admitted at the top and the water of condensation is removed from the bottom by an Edwards vertical, compound, twin air pump, having steam cylinders 8 inches and 14 inches in diameter; air cylinder, 18 inches; with a stroke of 12 inches.

The special feature of this pump is the absence of both foot and bucket valves; the lower ends of plunger and cylinder are conical in shape, and water from the condenser flows by gravity to the bottom of the pump cylinder; upon the down stroke of the plunger this water is forced upward and through circumferential ports into the pump barrel above the plunger, being discharged upon the up stroke.

The circulating pump has a capacity of 3,500 gallons per minute, and is of the centrifugal type, direct connected to a 10-inch × 10-inch steam engine.

Four units, with a total output of 2,450 kw., comprise the *Arc Lighting System;* two of these are of American make, one is French and one is German.

The French exhibit, made by the Delaunay Belleville Company, of Paris, consists of a complete installation, with engine, generator boilers, condenser and all auxiliaries.

The engine is of the vertical, inverted, six-cylinder, quadruple-expansion type, using superheated steam of 300 pounds pressure, with a normal rating of 1,500 horsepower; the cylinders are in three sets, each having two cylinders in tandem; the crank shaft is in one piece with three cranks; no separate fly wheel is fitted.

The top row of cylinders consists of the one high-pressure with a first intermediate-pressure on either side, while in the lower row the second intermediate-pressure cylinder is in the middle with a low-pressure on either side; the diameter of all upper cylinders is 340 mm. (13.4 inches), and that of the lower ones 680 mm. (26.8 inches), the common stroke being 470 mm. (18.54 inches), and revolutions per minute, 335.

The valves are all of piston pattern, driven by eccentrics on the crank shaft; one valve is fitted for each cylinder, except the second intermediate, which has two; the valves for each of the pairs of cylinders in tandem are on the same rod.

The governor is of the centrifugal throttling type, placed inside the crank case and driven by bevel gearing on the main shaft.

The condenser is of the cylindrical surface type, located at one

end of the engine about the level of the lower set of cylinders. The air and circulating pumps, the former of plunger type and the latter centrifugal type, are immediately under the condenser, being direct driven from the main shaft.

The generator is connected to the main shaft at the end opposite to the condenser, while the exciter is placed just outside of the generator, and is also direct driven from the main shaft.

The whole installation is very compact, occupying a floor space of about 35 feet × 15 feet.

The generator was built by the Société L'Éclairage Électrique, of Paris. It has a normal output of 1,000 kw., delivering a 2,400-volt, 3-phase, 50-cycle current. It is of the revolving-field type. The exciter, built by the same company, has a capacity of 27 kw. and furnishes a 90-volt direct current.

The German engine is from the works of the Société Alsacienne des Constructions Mécaniques, of Mulhouse, and its generator from the same company's establishment at Belfort, France.

The generator has a normal output of 700 kw., the current being of 2,300 volts, 3-phase, 50 cycles.

The engine is of the horizontal, tandem, compound type, with cylinder diameters of 600 mm. (23.64 inches), and 1,100 mm. (43.34 inches), stroke, 1,300 mm. (51.22 inches); revolutions per minute, 94.

There are two steam and two exhaust valves for each cylinder; they are of the horizontal balanced piston type, placed at right angles and tangential to cylinder bore; the valve mechanism is operated by eccentrics on a longitudinal shaft, which is driven by bevel gears on the main engine shaft. The gear of the high-pressure steam valves is of the releasing type, having horizontal dash pots; all other valves obtain their motion through a combination of cranks and levers very cleverly arranged.

The governor is of the spring-and-weight type, driven by spiral gearing from the longitudinal shaft; it is fitted with a counterbalance weight, by means of which the tension of spring can be varied while the engine is running.

The condensing equipment consists of a surface condenser, with about 2,070 square feet of cooling surface; an air pump

driven from engine crosshead; and a motor-driven centrifugal circulating pump; all located in a pit below the floor level.

There is no fly wheel other than the rotor of generator which is of heavy construction with the field coils on the circumference; it is mounted on the shaft between the main bearings. A 33-kw. exciter, delivering a 110-volt current, is mounted on the shaft outside the main bearing.

Another type, better known in Europe than in America, is the 1,000-horsepower Willans central-valve engine, exhibited by the Bradley Manufacturing Company. This consists essentially of three vertical, tandem, single-acting, triple-expansion engines, all working on the same shaft; the cylinder diameters are 340 mm. (13.4 inches), 520 mm. (20.49 inches), and 820 mm. (31.3 inches; stroke, 340 mm. (13.4 inches); revolutions per minute, 277.

The pressure on bearings is always from above, the work being performed on the down stroke only; half brasses are used, the other part being replaced by light straps. The crank case is closed, and contains oil and water in which the cranks revolve.

The three pistons of each section are mounted on the same hollow rod, and operate the crank through two parallel connecting rods; the eccentric for operating the valves of each section is forged on the crank pin at the middle of its length, and the hollow piston rod serves as a valve chest.

The engine is direct connected to a Stanley 600-kw., 2,300-volt, 2-phase, 60-cycle alternator. A 50-horsepower compound Willans engine, direct connected to a 30-kw. Northern electric generator, furnishes the current for excitation of the field magnets and for the operation of a motor-driven circulating pump.

A condensing outfit is installed in connection with the Willans engine, which consists of a Worthington surface condenser having 2,000 square feet of cooling surface, an 8-inch Worthington volute circulating pump and an 8-inch × 16-inch × 12-inch Blake, vertical, twin-beam air pump.

The arc system also includes a 200-horsepower, single-cylinder Skinner automatic engine direct connected to a Warren 150-kw. alternator, the following being the principal characteristics of the installation: Engine cylinder 18 inches × 18 inches;

revolutions per minute, 212; current delivered, 2,300 volts, 60 cycles, single phase.

The 250-volt current available for general use is supplied by a Greenwald, 600-horsepower, horizontal, cross-compound engine, direct connected to a Fort Wayne 400-kw. generator.

The cylinder diameters are 18 inches and 36 inches; stroke, 42 inches, and revolutions per minute, 100.

Slide valves are used for both steam and exhaust, the motion being obtained by means of horizontal cam shafts driven by gear wheels on the main engine shaft; the steam valves have a releasing mechanism and vertical dash pots.

A weighted governor, driven by gearing on the high-pressure cam shaft, controls the cut-off in both cylinders; an automatic stop of the Springfield pattern is also fitted.

A second installation, supplying a 250-volt direct current, is that exhibited by the Weber Gas and Gasoline Engine Company, consisting of a complete gas-operated plant with producer engine and generator.

The engine has a rated capacity of 125 horsepower, and the generator an output of 75 kw. The producer is of the suction type; the fuel—in this case charcoal—is fed in at the top, and the gas is drawn off above the center. The gas first passes through a small boiler attachment into the scrubber; thence to the receiver, from which it goes to the engine. The boiler attachment is intended to furnish vapor, which is admitted to the producer for the purpose of increasing the calorific property of the gas; the heat required to vaporize the water is obtained from the hot gas as it leaves the producer. In the present case, however, this arrangement is not in use, as the necessary moisture is obtained from the engine exhaust. In the scrubber the gas meets a spray of water which serves to remove the soot and other impurities held in suspension. For starting the engine compressed air is used; afterwards the engine itself draws the gas from the producer, the amount used being dependent upon the speed.

The 110-volt direct current is furnished by an American Ball, 200-horsepower, horizontal, compound, automatic engine, direct connected to a 125-kw. generator, manufactured by the same

company. The engine dimensions are: Cylinder diameters, 14 inches and 22 inches; stroke, 16 inches, and revolutions per minute, 230.

Steam for the entire plant is furnished by fifty-two water-tube boilers installed in the Steam, Gas, and Fuel Building. Of this number thirty-five, with all their accessories, are furnished as exhibits.

A set of sixteen Babcock and Wilcox boilers supplies steam for the four 3,000-horsepower Westinghouse engines through two 12-inch steam mains. Each boiler has a rated capacity of 400 horsepower, contains 81 square feet of grate surface, 4,000 square feet of heating surface and is designed for a pressure of 175 pounds. Roney mechanical stokers are fitted in these boilers. The feed water is supplied by three pumps, and is passed through Sorge-Cochran heaters and purifiers before entering the boilers. Induced draft is provided by four steam-driven fans, two being located at the base of each smoke pipe.

The largest exhibit of boilers is that made by the Aultman & Taylor Machinery Company, consisting of sixteen horizontal and three vertical boilers of the Cahall type. Four of the horizontal boilers are designed for a pressure of 225 pounds per square inch, being used for operating the steam turbines; they have each a rating of 508 horsepower with 73 square feet of grate surface and 5,080 square feet of heating surface. The other Cahall boilers are designed for a pressure of 175 pounds per square inch. Of the remaining twelve horizontal boilers, four have a rating of 508 horsepower each, and eight a rating of 400 horsepower each, the former containing 73 square feet of grate surface and 5,080 square feet of heating surface, the latter 65 square feet of grate surface and 4,000 square feet of heating surface. The vertical boilers are rated at 250 horsepower, and contain 51 square feet of grate surface and 2,536 square feet of heating surface. All of these boilers are equipped with chain-grate stokers manufactured by the exhibitor.

The next installation in point of size is that consisting of eight 400-horsepower Heine boilers, each with a grate surface of 72. square feet and a heating surface of 3,050 square feet. This

exhibit is equipped with chain-grate stokers furnished by the Green Engineering Company.

For the operation of its 1,500-horsepower engine the Delaunay Belleville Company furnishes three 500-horsepower boilers of the marine water-tube type, fitted with superheaters and economizers. They are built for a working pressure of 300 pounds, and each has a grate surface of 64 square feet, a boiler heating surface of 1,113 square feet, economizer surface of 395 square feet and superheater surface of 580 square feet, making a total of 2,088 square feet.

Two other marine-type boilers are exhibited by the J. & A. Niclausse Company. They are rated as 400 horsepower each. and contain 52 square feet of grate surface with 2,070 square feet of heating surface. The working pressure is 225 pounds.

For all of the exhibit boilers referred to above the Buffalo Forge Company furnished the induced draft equipment.

A 500-horsepower Dürr boiler of the marine type is also exhibited; it has a grate surface of 54 square feet, and heating surface of 2,282 square feet.

The Schuette-Kessel-Konsortium, of Geestemuende, Germany, exhibits a marine boiler, which is a combination of the water-tube and fire-tube types. It has a large, central, horizontal, ellipsoidal drum fitted with tubes parallel to its axis; two upper steam drums at right angles to the central one; and three water drums, two parallel to the central drum, the third connecting these two at the back ends. A set of small tubes connects this rear water drum with the upper rear steam drum, the latter being connected by a pipe to the front steam drum, to which the main steam pipe is attached. The grate is located beneath the central drum, and the flames impinge on its lower side, from which they are deflected into the nest of small tubes at the rear and thence through the tubes of the central drum to the uptake, coming in contact with the front steam drum as they leave the boiler. This front drum is intended to act as a superheater or dryer for the steam. The boiler contains 46 square feet of grate surface and 1,640 square feet of heating surface.

Two Climax boilers complete the installation. They are rated

at 300 and 250 horsepower, and contain 56 square feet of grate surface each; the former has 2,637 square feet of heating surface and the latter 2,235 square feet.

The feed-pump installation consists of eleven pumps, representing seven different makes, all furnished as exhibits; they are located in a pit at one end of the building.

Three different systems of feed-water purification are exhibited, one a purely chemical process, the second a combined chemical and mechanical, and the third mechanical.

For fire-prevention purposes there is an installation consisting of fourteen 1,000-gallon Worthington, Underwriters, fire pumps. These are all kept constantly under steam, the throttle valves being controlled by pressure regulators.

A complete overhead link-belt system supplies coal to the boilers; the cars enter the building at the west end and dump their coal into hoppers, from which it is passed through a crusher and delivered to the storage bin; an inclined conveyor removes the coal from the bin and delivers it to an elevator, which in turn delivers it to an overhead conveyor running along the south side of the building. From this line cross conveyors branch off at right angles and serve to carry coal to hoppers located above the front of each boiler; chutes from the latter deposit it on the grates.

Ashes are removed by small cars operating in underground tunnels along the boiler fronts, these carry the ashes outside the building, where a hoisting device loads them into cars for removal from the grounds.

For the operation of exhibit gas engines a 350-horsepower engine gas plant, with a capacity of about 30,000 cubic feet per minute has been installed by R. D. Wood and Company.

Three Worthington centrifugal pumps are provided to supply water for the cascades, each has a rated capacity of 30,000 gallons per minute against a total head of 152 feet when operating at 365 revolutions per minute. They are driven by 2,000-horsepower direct-connected induction motors.

The steam mains from the boilers in the Steam, Gas, and Fuel Building to the engines in Machinery Hall are carried in under-

ground tunnels, and the wiring for all purposes throughout the grounds is underground.

A compressed-air service is maintained for the use of exhibitors, the air being furnished by two Laidlaw-Dunn-Gordon compressors, with displacements of 1,320 and 530 cubic feet respectively.

REGARDING USEFUL INFORMATION.

By Commander A. B. Willits, U. S. N., Member.

Many who are professionally, or otherwise, interested in the Naval Service appear to consider the Navy Department as an omniscient Being, somewhat tyrannically guiding the destinies of ships and personnel, with full knowledge of their defects and needs.

When results are apparently bad, or not in accord with the critic's views, the fault is ascribed to neglect or carelessness on the part of this Being, or to some secret motive which must not be too rashly inquired into. Seldom is ignorance conceived to be a possibly conducive attribute, as, of all the various functions exercised by the Department, that of receiving and storing information in its various Bureaus, is believed to be the most extensive.

Tons of reports, designs, suggestions and recommendations flow annually into its maw and are supposed to be quickly digested and assimilated, and it is a constant source of popular surprise that reformations and changes in both construction and details do not promptly materialize as a natural consequence. Hence, throughout the service, one hears frequent queries of "Why does the Department allow this or that condition to exist, or allow such and such class of designs to be incorporated in new ships; or so and so to hold such and such a billet?" queries covering the entire range of administration and almost always with the appended, decided statement of what the speaker would do were he Secretary of the Navy.

Of course, this conception is only inferential from the criticisms and attitude of a majority in the Service, and yet, while every one really is aware of the complex nature of the Department, only the few who have had intimate personal experience

in its Bureaus, or have composedly studied the conditions governing them, can realize the adverse influence and hampering effect produced upon the business of the offices through ignorance or wilful misconception of the methods by which the Department work is conducted, or by failing to consider the Department as a System instead of Being.

It is not intended to imply by the above that a universal enlightenment on the subject would alter any line of general policy or revolutionize the type of war ships. We have an efficient Secretary of the Navy and his cabinet for the former, and these, with a Board on Construction, fully capable of properly caring for the latter; but it is in the realm of details, where the Secretary of the Navy and the big Boards enter not; where the work is so vast, and of such constant and varying interest, that the twenty-four hours of every day are too few to enable any individual to even comprehend it all; it is in this realm that vastly greater progress and improvement can be made if the departmental conditions are properly understood.

The effectiveness of our fleets depends upon the degree of perfection that obtains in the details of hull, machinery, armament and equipment. A battleship of ideal type and great tonnage would cut a sorry figure in battle with a jammed rudder, stopped air pumps, stuck-fast turrets, or burnt-out dynamos; and while we have, in the Department System, separate Bureaus for each of these sub-branches, it is not difficult to comprehend the fact that perfections in design cannot be wholly originated in such Bureaus, and that for proper advance towards perfection the Bureaus must depend upon information from those practically experienced with already existing designs.

As the Secretary of the Navy must depend upon his cabinet of experts (the Bureau Chiefs) for his complete success in office, so does each Bureau Chief, in turn, depend upon his assistants for a safe and progressive administration of his Bureau. The Bureau work must be sub-divided, with efficient sub-heads, who, by careful study of their particular branches, become able and reliable cells of the official brain.

The remarkable point in this compound brain is that all the

cells can cerebrate at the same time without interference with each other; but the results of their cerebration depend upon the material upon which they are fed, and it is of the most vital importance that this food shall be both nutritious and digestible.

The tons of reports, designs, etc., etc., above alluded to compose the food for these brain cells, and to be nutritious they must be pertinent, and to be digestible they must be clear and correct. The daily menu at a Bureau desk affords no epicurean feast, as all who have tried it well know; but the miseries resulting from badly prepared "food" have never been fully told. Think of the time lost and the work that is delayed by the enforced study of some ambiguous report, lest something of importance should escape, or the disorganizing effect of reviewing carelessly recorded or incorrect data from experiment or test. Remember the stream of correspondence ever coming in, and realize, if you can, the small part of a day that any one expert can devote to the average letter or report under his particular cognizance, and then wonder, if you dare, that so many papers fail to receive expected action and are filed away "for future reference."

Properly nourished, all these brain centers become abnormally developed as expert critics and detectors of defects in designs and arrangements, and, combined, form a wonderfully efficient and indispensable system, a sort of clearing house, by and through which the vast interests of shipbuilders, navy yards, fleets and stations are regulated, their differences reconciled and a conservative influence exercised in preventing extravagance.

The object in view in thus outlining the conditions governing the work in the field of material in the Department is to bring about a fuller appreciation of its requirements and to indicate the possibility and duty of every intelligent member of the Navy personnel of becoming a potent agent and valuable aid to the System in the field of observation.

No one active in the service will acknowledge lack of interest in constructive progress and improvement, but many there are who contribute nothing towards this advance, either through indolence or because they do not know how to go about it. Still others make attempts, but fail of good results.

They don't know how to prepare the "food" they send or do not take the necessary time to properly prepare it, and a few suggestions along this line may find some application.

There are many who are content with performing simply that routine work which is demanded by their orders. Often this is not sufficient to really occupy half their office hours. Leisure for other matters is found, and if not, lassitude or ennui is probable. But it seems to me that it is only necessary to excite the interest of such moderately occupied folk in some technical problem to at once secure profitable thought thereon. But it is a primary duty for each one thus situated to shake off any lethargy that may be creeping over him and to regularly devote some of his daily time to close observation and criticism along such special lines as may be accessible.

First, refuse to be satisfied with any faulty detail simply because it was approved by the Department. There is no better training than in studying out methods of practically overcoming faults in existing details in any branch. Bear in mind, however, that it is not a matter of vital importance that your mere criticism shall get to the Department *by wire*. Ships will continue to float while awaiting your conclusions. *Take time*. This does not mean procrastination, for *now* is never too soon to work at an improvement. Take as much *now* as you can, but keep on with such a full and sufficient number of *nows* as will positively assure you: first, that your criticism of the detail was well founded; second, that its improvement is important; and, third, that your suggested change is practical, justifiable and clearly demonstrated in your report. Then send it along, and if you are positively informed as to the desirability of a similar change at other places do not fail to recommend it. Do the full and proper work in preparing the "food" for the brain cells there in the Department, and do not send in a lot of separate ingredients for them to mix and season, and then feel aggrieved at lack of proper consideration.

I cannot lay too much stress upon this point of proper preparation of documents sent for Bureau action. Some people, when they get an idea in their heads, seem to think that the whole

thing must be clear to any one who looks them in the eye. They sketch a few crooked lines, and ejaculate a few disjointed words, and then are amazed at failure to comprehend on the part of the listener. This class will always read between the lines of their own official recommendations and actually believe that their ambiguities are as lucid as a demonstration in Euclid.

Better take days or weeks or months in careful preparatory work to get an important idea into practical and economical shape than to rush it in, half developed and wholly indigestible, as a mere breeder of mental dyspepsia.

Next, keep in mind that incorrect data are far worse than none at all. These mislead, and cast unfair doubt on other records. In experiment or test never send in guesswork, however disagreeable or humiliating it may be to own to failure in securing the proper figures. "Monkeying" or "jockeying" with such records is criminal. Get correct data as far as is possible on every test. Get plenty of it, too, as there is a human weakness tending to make observers confident of their ability to remember the minor points in experimental work. This is a delusion which has frequently robbed reports of their value.

After securing the data use every ounce of your thinking apparatus in arranging it so as to be most readily comprehensible. Do not begrudge the time and work necessary to strike averages and to clearly set forth your deductions. You are thus preparing good "food" and are making yourself a potent agent in the advance of your profession.

Papers submitted to the Department in accordance with these precepts are self-stamped as of importance and value, incomparably greater than that of the simple suggestion, or hasty criticism so frequently dished up on Bureau tables.

Finally, and perhaps of most immediate importance, I come to the special field of shipbuilding, and the superintendence thereof by the various naval inspectors.

At present there are nine private shipyards engaged in building naval cruising vessels. The Bureaus prepare the specifications and make the general arrangement plans for each vessel, leaving the great mass of details to be worked out by the contractors. These details, in the case of the machinery alone for a

battleship or large cruiser, necessitate about six hundred separate designs or drawings, each of which is subject to the careful criticism of the inspector of machinery before it is forwarded for that approval of the Bureau which warrants procedure with the work. The recommendation of the inspector is frequently of great weight in influencing the Bureau, as he is on the spot and can actually see conditions that would be very difficult to clearly picture from simple observations of the drawings. The mental combination of, say, the pipe plans of a compartment, three views of which are necessary to complete the working drawings, is possible only to a three-headed man; and, however careful the draftsman may be, the actual run of these pipes eventually differs from that designed in some points where unforeseen interference occurs.

It frequently happens that sister ships are built by separate contractors; and in working out their own designs for some important detail, they present greatly varying forms for its construction. Each is responsible for the efficiency of its work, and the individual inspector, knowing no other better form, recommends approval and secures it. With forty odd vessels building at the same time a comparison of all details by the Bureau is out of the question, and, indeed, the several forms each filling the requirements of the specifications, renders this unnecessary.

But there is always a way for the inspector, *if he knew of a better design* than that submitted for his criticism, to guide the contractors to it. Indeed, the builders will always be found ready to incorporate improved devices. They want to build well and send out good ships, and are grateful for timely suggestions pointing to real improvement. Naturally they do not want to rebuild or make over parts already finished under approval, but they appreciate points from the experience or knowledge of the Naval Inspector. But frequently they get no such assistance, and merely build from their own conception of what is best, with the result of all isolated work. They frequently struggle with difficulties already long overcome by other builders, and stumble over them in better or poorer shape than did the others, according to their ability. From this, one ship of a class will

have some details or arrangements much more nearly perfect and decidedly more effective than her sister ships building elsewhere.

Now it happens that all these ships are building for the same firm, "Uncle Sam and Company," and Uncle Sam has the right to see that they are all as uniformly perfect as possible. Shipbuilders like to guard their "practices" from their competitors, and they do not send cards to each other to come over to inspect each other's works at leisure. But trade secrets now-a-days are few, and there is no more reason for such discrimination than there would be in house building.

In this view, therefore, it is of the very highest importance that inspectors shall keep in touch with each other regarding the important features of constructive work coming under their supervision. The knowledge of the "various practices" in shops and ships broadens their views and enhances the value of their services many fold, and is, more than all else, the best guarantee that the new vessels will have a minimum of defects. Visits to shipyards distant from their own, interchange of ideas and discussion of difficulties by direct correspondence, with sketches or prints to illustrate important points, would all assist wonderfully in this work of amelioration, and such means should be used freely.

It would be a narrow view for any inspector to hold that it is to his credit to have more efficient devices and better arrangements on the ships he is supervising than are installed on other ships by competing firms. Rivalry in excellence of workmanship is a different matter, and should be encouraged; but the Government wants every possible benefit to be given to every new ship to secure the economy and effectiveness of its plant, and I am quite convinced that some steps towards establishing this fuller and freer interchange of information among the Naval Inspectors would directly and greatly redound to the benefit of the Navy Department, and establish, perhaps, a saner freedom of intercourse between the several builders.

To be properly serviceable information must be kept in circulation in its legitimate channels. Pigeon-holed, it leads to duplication of defects.

NOTES FOR GENERAL AND ROUTINE WORK OF ENGINEER'S DIVISION, U. S. NAVAL VESSEL.

By Lieutenant H. C. Dinger, U. S. N., Member.

Preface.

The following outline of matters affecting the organization and work of the Engineer Force of our Naval Vessels has been compiled with the idea of furnishing a suggested general guide for the use of Officers and Petty Officers doing engineering duty.

It has been the aim of the writer to group together those matters contained in the steam instructions of the U. S. Navy Regulations in a more convenient form for reference, and to make such additions to these as the latest developments of naval engineering indicate to be the best practice.

The part relating to organization and administration is suggested to the service for trial as being the result of successful practice on various vessels and, as far as possible, in conformity with present conditions.

It is hoped that an extension of this idea may soon be forthcoming in official form wherein the various parts may be more extensively investigated and outlined than I have been able to do by personal effort. Any criticisms or suggestions in regard to the subject matter of this paper will be gladly received by myself or by the editor of the Journal.

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PART I.

GENERAL MATTERS FOR GUIDANCE OF OFFICERS.

SENIOR ENGINEER.

The duties of the Senior Engineer cannot of necessity be strictly defined, but it is expected that every officer detailed to such work will regard the duty as one of trust and responsibility, and of such importance as to demand his conscientious and undivided attention to its performance.

While the performance of detail duties must often be assigned to subordinates, the Senior Engineer should always recognize the fact that the direct responsibility for the efficiency of the Engineer Department can only rest with the officer detailed as its administrative head.

It should be the object of the Senior Engineer to maintain the machinery in such condition as to be in readiness for developing maximum power at short notice, and an organization in accordance with this purpose should be secured.

Where the execution of any order relating to the operation of any appliance is likely to subject the machinery or vessel to subsequent injury or danger, it should be the duty of the Senior Engineer Officer officially to call the attention of the Commander of the vessel or the Senior Officer present to the possibility of such danger. Such representation should be made in writing wherever possible, so that the responsibility of each officer concerned for resulting consequences may be definitely determined.

Every facility should be given to advancing deserving and capable men, and all possible means should be taken in encouraging the enlisted force to fit themselves for higher ratings.

DAILY ORDER BOOK.

A daily book should be kept at the engine-room log desk, in which the orders for the night and morning will be entered each day by the Engineer Officer on duty, and also any orders for the execution of work below, changes in the disposition of machinery, etc. The Machinist or other Petty Officer on duty should be required to read over and initial these orders on coming on watch, and, on being relieved, will call the attention of his relief to any orders not executed.

ROUTINE ORDER BOOK.

An order book should be kept in the Engineer's office or in the engine-room log desk, in which all routine orders affecting the Engineer Department, manner of performing work, and special directions in regard to care and operation, will be entered by the Senior Engineer. These orders should be read and initialled by all Officers and Petty Officers who are affected or who may be charged with their execution. Matters affecting the Engineer Division in general should be published at quarters or posted on the Engineer bulletin board.

SENIOR ENGINEER'S REMARK BOOK.

The Senior Engineer's remark book should contain :

(1) A general history of the condition, repair, overhaul and operation of the various parts of the machinery. A special section of pages should be allotted to each part.

There shall be made at least one entry each quarter on the general condition of each part.

(2) A list of and the location and condition of all spare parts of machinery.

(3) Useful notes or information on the use, advantages or disadvantages of supplies and material, devices or systems used for care and operation. This should give information as to kind of material and supplies that have been found best for various services.

The subject matter of the remark book should be properly indexed in order that the information may be easily accessible to any one desiring it, and to this end the subject matter should be divided into sub-heads in order that the desired description, etc., in detail, may be obtained.

Suitable card index books with separate sheets may be found more convenient for this purpose than bound volumes.

REPORT FOR INFORMATION OF BUREAU OF STEAM ENGINEERING.

In order that the Bureau of Steam Engineering may obtain information on the practical working of various devices and appurtenances in connection with the machinery installation, special reports on such matters should be forwarded whenever sufficient information and data have been obtained. Such reports should be concise and accurate, and should in general state actual results or opinions based on such results.

Such information is especially valuable on the operation of special tools or auxiliaries or new devices, material, supplies, fittings, systems of installation, and methods of operation.

Any information concerning changes in the fittings or installation of machinery tending toward economy, simplicity and general service efficiency should be concisely compiled and forwarded to the Bureau of Steam Engineering, where it may be used as a basis of information in making new designs.

DUTIES OF ASSISTANTS.

When detailed for duty with the Engineer Division, all assistants to the Senior Engineer Officer should, as soon as possible, make themselves familiar with the general machinery plans as well as with the general condition of every mechanical appliance for the efficiency of which the Engineer Force is directly responsible. To this end, blue prints of arrangements, etc., the machinery specifications, and various entries in the Senior Engineer's remark book should be carefully studied. They should give special attention to alternate disposition that may be made in case of accident or derangement, in order that they may be able to give prompt and correct orders when casualities take place. It is only when intimately acquainted with the run of the Department that prompt action in case of emergency can be taken, and it should not be necessary to depend entirely on a particular subordinate who may have a more detailed knowledge of the parts affected.

The duties of the assistants to the Senior Engineer are mostly those of supervision and direction, and in general terms are defined in the Navy Regulations.

Their chief work should be to assist the Senior Engineer in the general work of administering the affairs of the Engineer Department, the preparation of reports and compilation of engineering information for the use of the Bureau of Steam Engineering.

In accordance with the Navy Regulations, they will be assigned by the Senior Engineer to routine duties in connection with the care and preservation of the machinery and its various appurtenances, and in the performance of these duties they should see that all the requirements as to overhaul and inspection are properly carried out.

They will superintend and direct the special repairs on their own stations, but at such times shall be subject to the orders of the Engineer on duty.

They should prepare notes on the repair, operation and condition of the machinery under their care for entry in the Senior Engineer's remark book, and will submit a report of the condi-

tion of such parts, each under its own heading, for entry on the remark book at the end of each quarter.

Assistants to the Senior Engineer should use every endeavor to obtain reliable data on the operation of the machinery, on the advantages and disadvantages of different types of installation, and on such changes or alterations as might improve the efficiency of the Engineer Department in future designs.

They should use every opportunity for obtaining information as to machinery installation and operation on foreign vessels which they may be permitted to see; also engineering facilities of dock yards, ports and harbors; and in these matters they should work in conjunction with the Intelligence Officer of the ship.

Data or information thus obtained should be forwarded to the Bureau of Steam Engineering, as noted in the paragraphs under Reports for Information of Bureau of Steam Engineering.

SENIOR ASSISTANT.

The Senior Assistant will be assigned to the general duty of preparing stations, overhauling and correcting station bills, and of the general organization of the department under the direction of the Senior Engineer. He should prepare general directions for overhaul work and for internal regulations and procedure in the Engineer Department.

He will have special oversight of the work of instruction of the men of the Engineer Division in their duties, stations, and in general engineering knowledge. He will prepare courses of instruction for the men of different ratings.

WATCH AND DAY'S DUTY.

The assistants to the Senior Engineer will stand watch and day's duty in conformity to the Navy Regulations.

On relieving, all the new watch should be down and at their stations. The officer being relieved should inform his relief what boilers are under steam, and their general condition as to fires, leaks, etc., condition and operation of feed pumps, steam pressure, coal allowance, or revolutions to be made, from what bunkers

coal is to be taken, general condition of main engines and defects that have developed, hot bearings, etc., auxiliary machinery in operation, and its general condition. He should call attention to new orders in the daily order book, and give information in regard to any work going on in the Department.

After relieving, the Engineer Officer should make a careful inspection of the department, noting especially any pounding in engines, heating of bearings, signs of improper lubrication, adjustment of links, pressure in steam jackets, receivers and vacuum.

He should visit the fireroom frequently, to see that fires are properly cleaned and kept in proper condition, that a continual feed is kept on boilers and a proper water level held, that coal is taken from authorized bunkers and properly tallied, that all leaks and other defects have been reported, that the established routine is carried out, and that all directions contained in steaming regulations are adhered to.

DAY'S DUTY.—IN PORT.

On vessels where there are two or more commissioned officers detailed as assistants to the Senior Engineer, they will take day's duty in rotation. Warrant Machinists may, in addition, be assigned to day's duty, but in general on vessels where there are commissioned officers as assistants, the services of Warrant Machinists should be utilized for special direction and oversight in making repairs and the performance of expert mechanical work. When not on watch, Warrant Machinists should be required to be on board during working hours while work is going on in their stations. In general, the number of persons standing watch should be limited to actual necessities, since by so doing more are available for the actual work of overhaul and supervision.

On vessels having no commissioned officers as assistants, Warrant Machinists will take day's duty in rotation as Engineer Officer-of-the-Day.

On vessels having no Warrant Machinists, Chief Machinists or other Petty Officers will take day's duty as Engineer Officer-of-the-Day.

All rules and regulations in regard to Engineer Officer on watch will apply in all cases to whomever is performing that duty.

TURNING OVER DAY'S DUTY

The Engineer Officer-of-the-Day coming on duty for the day will relieve within a half hour after "turn to" in the forenoon. The officer turning over the watch should be in a position to report:

What bunkers coal is being used for.

The machinery, valves, watertight doors, etc., moved, temperature of bunkers and saturation of boilers taken.

Whether morning orders have been executed and what parts remain to be done.

The men turned to at their proper stations and the work of day detailed and begun.

The absentees sick and excused.

The work that will be required in the immediate future.

The daily work list prepared to turn over.

The boilers and auxiliary machinery in operation.

What steam launches are running.

The extent and condition of auxiliary watch.

The officer relieving should, on receiving this information, take precaution to read over the order book for the work of the day and note completed and uncompleted work, the different jobs going on, and the Petty Officers in charge of each part of the work.

He should prepare to make the necessary disposition for the drill of the day and should obtain the necessary information in regard to drill and exercises from the Senior Engineer or the Executive Officer.

The Engineer Officer-of-the-Day will not go to morning quarters, but will be below to direct the work of the department.

He will accompany the Senior Engineer on the A. M. inspection and note any directions received in the daily order book.

He will see the department properly cleaned up after working hours, and should require the storeroom keeper to report all tools in.

At preliminary evening inspection he should receive a report, from the Machinist or Oiler on watch, of the quantity of fresh water in reserve tanks, the double bottoms sounded, bilges pumped, unnecessary lights out, and all watertight doors, except those necessary for communication, closed.

After making the preliminary inspection in the evening the Engineer Officer having day's duty should obtain directions from the Senior Engineer and post the orders for the night and morning in the daily order book. The Petty Officers and leading men should then be informed of the proposed work for the morning in order to avoid delay. At the same time valuable suggestions may be received.

WARRANT MACHINISTS.

Warrant Machinists should make themselves familiar with all matters relating to the responsibility of officers and the general regulations in regard to the administrative work of the Engineer Department, and as such they should become familiar with the general requirements and duties of Divisional Officers in connection with the supervision of the men in their sections. They should be especially familiar with all matters treated in the Engineering Instructions of the Navy Regulations, and, from other sources of authoritative knowledge, they should keep themselves informed on the latest practice of operating marine machinery and the execution of mechanical work in connection with the machinery installation of vessels. They should keep note books, in which to enter matters of current practice and operation, repair and fitting of marine machinery.

The Warrant Machinists should be detailed in charge of subdivisions of the machinery installation, and will be directly responsible to the Senior Engineer and his assistants for its proper efficiency and condition.

In all cases they should superintend and direct the work on their stations, and when special expert mechanical work is necessary they shall personally perform it. The ability to perform expert mechanical work will always be considered one of the important qualifications for the position of Warrant Machinist.

In Charge of Section.—A Warrant Machinist should be placed in charge of each section of the Engineer Division and should be responsible for the general instruction of the men of his section for drill, their general knowledge of stations and duties and the general appearance and condition of their clothing. He should prepare clothing lists and monthly requisitions.

PART II.

RATINGS AND QUALIFICATIONS OF MEN.

The composition of the Engineer Division on board ship is determined by the Bureau of Navigation, and depends on the machinery installation and available space on board.

Chief Machinists.—The most important rating is that of Chief Machinist. Every effort should be made to train men who have the desired qualities to become proficient in the duties of this rating.

The qualities to be looked for in a Chief Machinist are:

Mechanical ability.
Knowledge and experience in service methods.
Capacity for control and handling of men.
Ability to supervise and direct work.
Reliability, and sobriety of conduct.

A Chief Machinist must be able to do skilled machine work and must be familiar with the use and operation of ordinary machine tools. This is, in most cases, learned in shops on shore, but there men often learn only a specialty, so that they have not the general knowledge so greatly needed on board ship. Men whose experience has been gained in small shops are more likely to have the desired general knowledge than those who have been in large establishments where specialties are a feature. Men who have been rated up in the service can, by close application, become proficient in doing machine work, but the experience gained in shop work on board ship is limited, and the opportunities for becoming proficient in this work are not the best. For this reason, special opportunities should be given, and

it is for this purpose that the mechanics' schools at the navy yards are established.

The capacity for control and handling of men depends on natural adaptability in that line, natural executive ability, education, nature of training, and length of service. Reliability and sobriety are extremely important in a Chief Machinist and must be carefully considered. An examination of conduct records for infractions of regulations will be useful in determining fitness.

Knowledge and experience in service methods and ability to supervise and direct work are gained by actual service; some gain this knowledge much more readily than others, however, and it is not, therefore, necessary that a man should have a great many years' service in order to be a chief petty officer.

To obtain material for Chief Machinists the ablest Machinists, 2d class, should be given every opportunity for learning service ways, methods and necessities, and of becoming familiar with the practical work that can only be learned on board ship.

Coal Passers and Firemen who show an aptitude for mechanical work should be given special opportunities by detail as helpers to Machinists, in order that their abilities may be developed. It is important that such men obtain this experience and knowledge while young, before their natural energy has been lost.

Chief Machinists should be promoted from Machinists, 1st Class, who are the most reliable and intelligent, have good ability for handling men, good mechanical ability and knowledge of service needs and requirements.

Chief Machinists should be allowed considerable latitude and independent authority in the control of men and direction of work. Their orders must be regarded as authoritative and must be sustained by superiors in all possible cases. They should be allowed special privileges, in order that they may better command the respect of the other men.

Machinists, 1st Class.—These will be men of two general classes: (1) experienced mechanics, who have not the necessary qualities for a chief petty officer; and (2) younger and less experienced men on their way to promotion. A Machinist, 1st

Class, should be a good mechanic, and be familiar with the operation and installation of marine machinery.

Machinists, 2nd Class.—These will be either newly enlisted machinists, of little or no sea experience, or men advanced from Oilers or Friemen who have relatively less ability in mechanical work.

Those who have learned their trade outside will probably make the best machinists; while those who have worked up in the service are probably more familiar with the operation of machinery and more reliable and handy in case of emergency. This rating may be considered as a transitional one, and one from which men should be promoted as soon as their abilities entitle them to advancement.

Oilers.—Oilers should be selected from experienced Firemen, having good mechanical ability and knowledge of marine machinery. Men who are especially adapted for the rating of Water Tender should not be made Oilers, since an Oiler is more easily trained than a Water Tender. An Oiler should be reliable, quick and alert. He should have a fair amount of mechanical ability and and a good general knowledge of the machinery installation of a man-of-war. He should be familiar with the operation of pumps and auxiliary machinery, should understand drainage and feed systems and other piping systems, operation of evaporators and ice machines. He should be able to make minor repairs, such as repacking glands or joints, grinding in valves, and disconnecting and assembling various parts of machinery. He should be familiar with methods of cleaning and painting engine rooms, double bottoms and bilges, and with the ordinary measures taken for the preservation and care of marine machinery.

Boilermaker, Blacksmith, Coppersmith.—Men having these ratings should be proficient at their trades. In addition, every opportunity should be taken to train these mechanics in the handling of men and direction of work.

Engineer Yeoman.—The Engineer's Yeoman should have a knowledge of keeping accounts and the preparation of requisitions and official reports. He should be a proficient typewriter, and should have a general knowledge of the class of stores and

supplies required in the Engineer Department, and the proper means of storing same on board ship.

Chief Water Tenders.—Chief Water Tenders are selected from the Water Tenders who have special ability as chief petty officers, and are appointed in a manner similar to the other chief petty officers. In accordance with Gen. Order No. 134.

Water Tenders.—Water Tenders should be experienced Firemen who have good qualities for handling men and who are resourceful and reliable, understand the operation of boilers and pumps and their care and preservation. They should be familiar with pumping and drainage systems, methods of cleaning, painting and overhauling boiler compartments, double bottoms, bilges and coal bunkers, the stowing of coal and the qualities of different coals. The duties of water tender requires especial executive ability, force of character and trustworthiness. Men who can show evidences of these qualities should be given every opportunity to acquire the requisite experience in order that the greatest number of men capable of filling this position may be trained. It is suggested that, for the good of the general service, whenever there are men on board qualified for this duty in excess of the number allowed, steps should be taken to transfer such men to other vessels where their services may be in demand.

Firemen.—Coal Passers should be advanced to the rating of Fireman 2d Class as soon as they acquire the necessary ability and experience.

Firemen 2d Class of light physique who have good mechanical ability should be assigned to such stations as blowers, storerooms, care of machine shop, and auxiliary machinery. Such men, when capable, should be advanced to the rate of Oiler without going through the rating of Fireman 1st Class. This may be done in accordance with Article 515, Amended, U. S. Naval Regulations.

No one should hold the rating of Fireman 1st Class who has not the proper strength and requisite ability to be a thoroughly good fireman.

Firemen 1st Class who have grown old in the service and who have not the requisite abilities for the rating of Water Tender should, if they are capable, be advanced to Oilers' rating or assigned to such work as operating evaporators, ice machines, or to other duty that requires experience, but not much hard work.

A Fireman 1st Class should be an able and experienced fireman, should have a general knowledge of boilers, and of their construction, care and operation, should be able to operate pumps and auxiliary machinery and be familiar with the general means of cleaning, painting and preserving boilers and boiler equipments.

A Fireman 2d Class should have a fair knowledge of firing and a general knowledge of the manual labor done in connection with overhaul and work of cleaning done in the Engineer Department on board ship and a general knowledge of the machinery installation.

Coal Passers.—Coal Passers should be men of good physique and able to do hard manual labor. They should, in general, be trained in the line to which they are best fitted. Every opportunity should be given to enable them to acquire the knowledge and experience that will fit them for the positions in higher ratings. To this end, they should be given opportunities to learn to fire, to oil, and to make minor repairs, under the direction of the Petty Officers and leading men.

GENERAL RULES RELATING TO RATINGS.

The sole basis for advancement in rating should be *ability to perform the work incident to the rate.* The practice of advancing deserving men to ratings that they are not properly qualified to fill *because there happens to be a vacancy* is suicidal to proper results. The holding of a rate must imply ability to do certain work. By proper recourse to the provisions contained in the Regulations, deserving men can be advanced to any rating for which they are properly qualified.

PART III.

STATIONS.

The Station Bill for the enlisted force should be as simple as possible and its provisions capable of being strictly enforced. Every individual must be held directly responsible for the performance of his particular work; in case any matter is neglected the one responsible will be made to remedy it, not some disinterested one.

The primary basis should be the steaming watch; the whole force being divided equally into three parts or sections, each having its proper proportion of the various ratings. Men should not be frequently shifted from one section to another if it can be avoided.

Repair Stations.

Petty Officers, Chief and 1st Class.—In general, all Chief Petty Officers and Petty Officers, 1st Class, of the Engineer Force should be assigned to definite repair stations and be held absolutely responsible to the Engineer Officer in charge of station, and to Senior Engineer, in case of small ships, for their repair and condition.

The men, especially the mechanics, should be stationed with regard to their individual ability, so that they may be placed where they will be of greatest service. Thus a Chief Machinist with large workshop experience would be better for the engine room than the boiler room, while a Chief Machinist, promoted from fireman, would not be the best man to put in charge of workshop.

Chief Machinists.—It is suggested that a Chief Machinist should be placed in charge of each engine room, one in charge of auxiliaries in boiler rooms, one in charge of auxiliaries outside of engine room, one in charge of workshop, and one in charge of steam launches. For very large complements the boiler plant may be divided into two stations, and so might also the outside auxiliaries where they are numerous. For small vessels, outside auxiliaries, workshop and launches may be combined under one

head. Where the complement of Chief Machinists is very limited, a Machinist 1st Class can be placed in charge of some of these stations.

The Chief Machinist in charge of engine room should be responsible for the proper repair and condition of all machinery therein. He should be assisted by a permanent detail of Machinists 1st and 2d Class, Oilers and Firemen. The detail of Firemen for engine room may, in certain cases, be somewhat shifting, since at times their services may be more needed in the boiler room.

Blacksmith.—The Blacksmith should have charge of the forge and blacksmith tools, the care of gear for operating sluice valves, watertight doors, and other mechanical gear for lifting valves, etc.

Coppersmith.—The Coppersmith should have a general oversight of the piping of the vessel, and provide facilities for the proper repair of leaks and the location of defects therein. He should be required to inspect the piping from time to time, and test such portions as give indications of having deteriorated.

Outside Auxiliaries.—The Chief Machinist in charge of outside auxiliaries should have charge of the steering engine, capstan, overhaul of dynamo engines, steam heating system, boat and crane winches, and piping outside of machinery compartments.

Workshop, Steam Launches.—The Chief Machinist in charge of workshop and steam launches should keep the tools and appurtenances of the workshop in proper order and make the necessary repairs to the launch machinery.

Boiler Rooms.—The Chief Machinist in boiler rooms should have charge of valves, pumps, blowers and ash hoists and general machinist work required for repairs to boilers. A man who has had fireroom experience should be selected for this detail. The Chief Machinists in charge of these stations should have Machinists, 2d Class, and men of lower ratings to assist, the number depending on the amount of work and the men available for detail.

Boiler Rooms, Cleaning.—The Water Tenders should have charge of the cleaning and general overhaul of boilers and boiler

compartments, and the repair work for such parts as do not require the special services of a Boilermaker or Machinist.

Stations at Auxiliaries.—Oilers, old Firemen, 1st Class, or light Firemen, 2d Class, of good mechanical ability, should be selected for stations at evaporators, ice machines, or other auxiliary machinery outside of engine room.

Cleaning Stations.

The cleaning stations should be assigned in a similar manner. Each engine room to be in charge of a Chief Machinist and the work divided into sub-stations among the Machinists, 1st and 2d Class, and Oilers assisted by the Firemen detailed for engine-room stations, each man or group of men being held absolutely responsible to the leading petty officer for a certain part, and those in charge of the large station for all parts under their care. These cleaning stations should be in the same compartment as the repair stations, and, as far as possible, the steaming stations.

Men stationed at evaporators, ice machines, blowers, etc., should be made responsible for the cleaning of these compartments.

For the Firemen having cleaning stations in engine room there may be some departure from this, since in some cases they would be most needed for work in boiler rooms for which they would be detailed as needed.

Auxiliary Watch.

The auxiliary watch should be stood by a portion of the regular steaming watch, the men shifting each week, so that each will get his proper share of watch duty. To go into sea watches from port watches, or *vice versa*, will then only involve increasing or decreasing the number of men on the watch, the natural sequence of watches not being disturbed. The auxiliary watch is a permanent one for the week and is not varied by steaming conditions.

Stations for Drills.

General Drills.—The Engineer Force should be ready for the general drills as they occur, for general quarters, fire quarters,

collision, abandon ship and clear ship for action. As the regulations require one-third of the force to be available for the Powder Division, the following is suggested as the simplest way of providing for a shifting detail:

Powder Division.—A number of Firemen, 2d Class, and Coal Passers, equal to one-half of the total number of men in each section, will have stations in the Powder Division. The men of higher ratings will be stationed in the engineer department.

At these general drills the Firemen, 2d Class, and Coal Passers stationed with the Powder Division should report to that division in every case when not on watch.

Distribution of Watches.—The *watch on* will, in all cases, remain on watch, making such preparations as are necessary. The men of *first relief* not having stations in Powder Division should go below to stations in engine and boiler rooms to assist the men on watch. The *second relief* not having stations in Powder Division should be stationed for machinery stations outside of engine and boiler rooms, such as stations at gear for operating valves, watertight doors, wreck clearers over machinery hatches, etc.; they will in general be a reserve for any case of emergency.

GENERAL INSTRUCTIONS FOR STATIONS AT DRILL.

The following general instructions are given for the work of the Engineer Division at general drill. They will apply to nearly all ships, and can be elaborated upon for special conditions.

CLEAR SHIP FOR ACTION.

Boilers.—Get all boilers ready for steaming, prime and light fires when ordered. For drill muster at stations.

Hoist all ashes.

Try forced-draft blowers, bunker and furnace fire extinguishers.

Try auxiliary feed line and auxiliary feed pump.

Close watertight doors not needed. Close forced-draft doors and armor doors in protective deck.

Prepare emergency tools, tube stoppers, plugs, etc.

Clear gear from boiler hatches and ventilators.

Lead out hose.

Try watertight doors, all valve lifting gear and automatic gear for boiler valves.

Engines.—Warm up and get engines ready; for drill muster at stations.

Try pumps on main and secondary drains.

Try all voice tubes and bells, engine and boiler-room telegraphs and signals.

Get oil lamps ready.

Lead out hose and get emergency tools and material ready.

Try watertight doors, sluice valves and operating gear.

General Quarters.

Watch on remains on watch. *First relief* having stations below, assist men on watch in extra work. *Second relief* having stations in Engineer Department, go to stations on gun and berth deck in connection with operating gear, etc., upper hose, and for clearing away wrecks.

Muster at stations, lead out hose, close watertight doors, stand by pumps and manifolds.

Men of Engineer Division, off watch and not stationed below, go to sations in Powder Division.

Men stationed at evaporator, ice machine, blowers, and all steam machinery above protective deck, shut down same and stand by, unless otherwise directed.

Fire Quarters.

The same general rules should hold as for general quarters, the same men being stationed in same compartments, except that those men not having stations below would generally be utilized to form a bucket line, or as a reserve to be called upon for various needs.

Collision Quarters and Abandon Ship.

The Petty Officers in charge of each compartment should be responsible for the closing of doors and getting pumps ready for pumping on drainage system. The same general rules as for

General Quarters should hold. The men *on watch* remain there, and start immediately to make provisions for collision, the *first relief* having stations below to assist. The *second relief* go to gun or berth deck stations, and those stationed in the Powder Division should report there. When the call for providing boats is sounded, the men, except a few in charge of the Petty Officers in each compartment, should go to provide the boats. At the call for abandon ship, the fires should be hauled or extinguished and safety valves raised, the Petty Officers in each compartment to see that every one is up and report to the men assigned to take the reports, who should always be in a known and convenient place. As soon as all reports are in, the fact should be reported immediately to the Executive Officer.

BATTERY WITH LANDING FORCE AWAY.

In this emergency provision for the battery dependence will be placed largely on the men of the Engineer Division, and with a little simple training their services may be of great value. The simplest arrangement is to provide that at this call all of the Engineer Force not in the section on watch or in battalion will go to the battery. For each station at the guns there should be two men of different steaming sections. Then one of these will always be available. When both are present at the gun one can drop back to the duties of providing ammunition, which, in most cases, are easily learned. This arrangement will always provide for the number at the guns being filled and a somewhat varied number for supplying ammunition.

A Sample Gun Crew.

5-Inch Gun.

No. 1	Yeo.	
No. 2	G. M.	
No. 3	6115 W. T.	6215 W. T.
No. 4	6231 F. I. C.	6331 F. I. C.
No. 5	6162 C. P.	6387 C. P.
No. 6	Mess Att.	

(NOTE.—This is a suggestion for a requirement which may not be present on some vessels. It has stood the test of practical working with marked success.)

This system enables the Engineer Division to acquire practical instruction at the battery on the days they are called upon, either every week or every two weeks, as may be required. The men that belong to the battalion should be taken equally from each section, and should be changed from time to time in order that as many as possible may obtain this desirable training.

Boat Drill for Instruction.—Some provision, in most fleets, is made for giving men of the Engineer Division exercise in boats. As a rule, this is done on Fridays, in port. This is a day that lends itself very well to the work, and the afternoon is preferable. A certain percentage of the Engineer Division should be sent out each week. A suitable system would be to send out the *second relief* section every Friday afternoon. Every man would thus be exercised in boats once every three weeks. In many cases it would be inadvisable to send the Chief Petty Officers or older Petty Officers for boat exercise—judgment must in such cases be exercised.

General Instruction.—Some amount of general instruction relative to drills and duties is extremely desirable and necessary, as well as some training in the use of small arms. If a special period is set for this, a program can be devised that can be made very interesting and useful to the men. Friday afternoon will in general be the most suitable time of the week. For this work, if the *second relief* is exercised in boat work, the *first relief* should be given a period of instruction, this being done at sea as well as in port.

Warrant Officers, Chief and leading Petty Officers should be made use of in the general instruction of the men of lower ratings. Each Warrant Officer should in general have direction of the instruction of the men of his section.

While steaming, men standing watch should be excused from all but general drills, and these should be as little fatiguing as possible.

A concise record of instruction given to men should be kept and entries made in log.

It should always be recognized that the care and operation of the machinery and its appurtenances is the primary and import-

ant province of the Engineer Division, and this must first be looked after, but opportunities for useful training and improvement must not be neglected and need not interfere with the primary matter of importance.

GENERAL RULES GOVERNING ROUTINE WORK.

The following general rules are designed for the purpose of obtaining uniformity in carrying on of the work of the Engineer Division:

General Instructions.—General rules for the operation and care of boilers should be prepared from available information, and this information brought before the men who are to operate them, in order that the general necessities may be understood, and that there may be a known and uniform standard for work and operation.

The same should be done in regard to engine room. These instructions should be simple and concise, so that the subject-matter may be easily grasped by the men. The rules should be drawn up when the vessel is first placed in commission, and modified from time to time as experience indicates.

Repair Book.—A repair book or file case should be kept in the Engineer's Office, available to all Officers and Petty Officers in charge of stations, in which necessary repairs, as they are noticed, should be entered under appropriate headings. The name of man reporting each repair should be entered, with such information as may be necessary. As the repairs noted in the Repair Book are completed, they should be so marked. This book would form a basis from which the Engineer's journal should be made.

In this book should also be entered stores and supplies likely to be needed or which are running short.

Reports on Coming Into Port.—Just previous to coming into port the Petty Officers in charge of each station should prepare lists of all defects or repairs necessary or desirable, submitting same to the Warrant Officer in charge, or, when there are no Warrant Officers, to the Engineer Officer in charge.

Rules for Carrying on Work.—The men of Engineer Force will

turn to at the Boatswain's call on deck, and should, unless otherwise directed, report to their repair station for directions from Petty Officer in charge.

Petty Officers in charge of working parties or stations will report absentees to the Engineer Officer of the day.

On leaving the machinery compartments men will shift their working shoes, so as not to soil decks.

Men at work on deck or outside of machinery compartments should in all cases be in regulation working uniform for the ship.

No clothes will be allowed to hang about engine room and none in fireroom except on clothes lines especially provided. Clothes will not be stowed about the engineer department except in authorized lockers or receptacles provided, or for which permission may have been obtained from the Senior Engineer.

Firemen and Coal Passers will, except when actually employed in engine room, use the fireroom ladders only.

Petty Officers in Charge of Repair Stations.—They will see that all cleaning and repair work is conducted in the most approved manner, and that in carrying on work proper precautions are taken in regard to protecting parts of machinery from dirt, rough handling or the improper application of paint or cleaning gear.

Especial care must be exercised to prevent grit, emery dust, filings and dirt from getting into bearings. Emery cloth should be used as little as possible, and in no case on a wearing part.

When emery cloth is being used or parts of machinery filed, precaution should be taken to see that gaskets are placed over ends of bearings and that oil holes are closed.

The Petty Officer in charge of a station will see that material and cleaning gear is not wasted and that tools are properly used and returned to racks or to store room; that the accumulation of oily waste or other debris is not allowed in unauthorized places, but that such substances are put in the iron receptacles provided, or burnt in the furnaces.

Daily Work List.—Daily work lists are a convenience, and on large vessels are a necessity, in order to keep a record of distri-

bution of work. On small vessels when the number of men is not large such elaboration may not be necessary.

Daily work lists should be prepared by the Engineer's Yeoman. The following system is suggested.

U. S. S.....; Daily Work List.
Engineer Division. September 3, 1903.

Name.	Duty.

The work list to be made on form as above. Under column "Name" to be entered all names of men in Division; under column "Duty" the work assigned for the day. When this is made out Petty Officers in charge can easily be furnished with a list of men who are to work with them and who are responsible to them.

The work lists should be kept for record and signed by Engineer Officer-of-the-Day.

These lists should then be entered in repair book, and from such information, the Chief Engineer can make out his report of repairs.

Responsibility for Work.—Each man should be held strictly responsible for all work coming under his charge. Men, especially Petty Officers, should be allowed as much latitude as is possible in manner of doing work, as it will be found in general that better work will be done if considerable scope is allowed for individual ideas.

The aim should be to teach the best and most approved methods; incorrect and bad methods of doing work should not be allowed.

When work has commenced on a job, repeated and unnecessary interference should be guarded against, and the nagging of men at work should be avoided as much as possible.

Precedence of Necessary Work.—Whenever there is *necessary* work to be done for preservation, for overhauling or for main-

taining steaming efficiency nothing should be allowed to interfere. The first aim should be to keep the machinery in an efficient state. *Emergency repairs should take precedence of everything else.*

Routine.—Work can be carried on much more easily and more efficiently if a routine applicable to the conditions is established and strictly followed. This routine should, however, take into consideration variations in conditions and must be made more or less elastic.

Morning Watch.—The morning period should be from "*turn to*" till twenty minutes before "*mess gear*" (this time being necessary for washing). On mornings that clothes are washed a sufficient time should be allowed for this purpose.

The work of the morning watch should usually consist of turning machinery not in operation, moving valves, watertight doors, etc., testing boiler water and taking temperature of bunkers, hoisting ashes, minor cleaning of stations, preparing tools and detailing men for the day's work.

Friday morning should be given to cleaning bilges, which work can very often be finished before breakfast.

A. M. and P. M.—The forenoon period, from "*turn to*" till a half hour from noon, should be confined to the work of the day. The afternoon period, from "*turn to*" after dinner till some time in the afternoon, depending on conditions, amount of work, etc., should be left to the discretion of the Engineer Officer.

Special Days.—Saturday, when there is no special work to interfere, should be devoted to cleaning stations. The cleaning of stations, however, should never be allowed to interfere with work in connection with the overhaul and preservation of machinery. Extreme cleanliness and general neatness is enjoined, but the maintenance of an excessive or an elaborate amount of bright work and the doing of unproductive work simply for the sake of appearance should not be exacted.

Wednesday and Saturday afternoons should be half holidays, and should not be interfered with unless absolutely necessary.

WEEKLY ROUTINE FORM.

	From "turn-to" till 20 minutes to breakfast.	"Turn-to" after breakfast until noon.	After dinner till time for knocking off work of day. (This may vary.)	Evening.
Sunday.....	Finish cleaning stations.	Prepare for inspection and inspection by Commanding Officer. [Preliminary inspection by Engineer Officer.]	Port watch. (Holiday.)	Evening inspection and reports.
Monday.....	Wash clothes, hoist ashes, move machinery and valves. Detail work and prepare tools. Clean stations.	Work of day. Drills as per orders.	Work of day.	do.
Tuesday.....	do.	do.	do.	do.
Wednesday.....	do.	do.	Half-holiday. Inspection of clothing, small stores, etc., as directed.	do.
Thursday.....	do.	do.	Work of day.	do.
Friday.....	Clean bilges, move machinery, etc.	Finish bilges and work of day.	Instructional drills, boats, etc. Inspect and test mechanical devices, compartments, etc.	do.
Saturday.....	Clean stations, move machinery, etc.	Clean stations; clean out wash rooms.	Half-holiday.	do.

Routine Watch at Sea.

ENGINE ROOM.

1. At relief get all orders.
2. Make inspection of all machinery in operation.
3. Read over log and remarks of previous watch.
4. Take log data each hour.
5. Test water in hotwell. } 2d hour.
6. Oil blowers. }
7. Pump bilges and clean strainers. }
8. Clean floor plates, etc. } 4th hour.
9. Oil blowers. }

FIRE ROOM.

1. Relieve watch, get all orders.
2. Clean fires during first hour; examine and oil forced-draft blowers if in operation.
3. Sweep tubes.
4. Haul out and sprinkle down ashes.
5. Blow through gauge cocks (not to be neglected).
6. Hoist ashes after five bells.
7. Get out round of coal; examine and oil forced-draft blowers, if in operation.
8. Clean up floor plates.
9. Allow cleaning fires to burn down, and pump up cleaning boiler.
10. Blow boilers through surface and bottom blow on watch, as directed; with water-tube boilers to be done at least once a day. Surface blow should be used whenever oil shows.

TABLE OF OVERHAUL REQUIREMENTS.

Daily.—Move all machinery not in operation and watertight doors. Take temperature of bunkers. Test boiler water with litmus paper, and take saturation.

Weekly.—Inspect mechanical devices for the safety of vessel, including sluice valves, and mechanical gear for operating safety, stop, drain and ventilating valves, mechanical tele-

graphs for transmitting orders, and all compartments outside of double bottom compartments. [*Art. 396, Par. 5, N. R.*]

Three Weeks.—Clean feed tanks. (See under General Engineering Rules and Regulations.)

Monthly.—Test and inspection of mechanical devices for safety of vessel. [*Art. 1637, N. R.*]

Test blowers and pumps that have not been used, or connections that have not been used. Flush main drain and try circulating pumps on drainage system.

Quarterly.—Inspect holding-down bolts. Regular inspection of boilers. All cylinders and valves, main and auxiliary. All pump barrels and valves. Examine and overhaul all auxiliary machinery. Examine valves in manifolds. Test or compare steam and vacuum gauges. Clean propellers and sea-strainers. Paint coal bunkers. [*Art. 1640, N. R.*]

Semi-Annually.—Test and examine outboard valves. Vessel docked. Grind in sea valves. Renew zinc protectors. Examine propeller shaft, stern bearings and lignum vitae.

Yearly.—Take inventory of stores. [*Art. 486, N. R.*]

Overhaul Requirements for Various Appurtenances.

Boilers.—Fire sides to be cleaned whenever steam is taken off.

Fire sides to be thoroughly cleaned after every two weeks' steaming.

To be thoroughly examined once in three months.

Blowers.—Test by running once a month. Overhaul each quarter.

Bunkers.—Paint once a quarter. [*Art. 1640, N. R.*]

Cylinders.—Open and examine after runs, and at least once a quarter.

Main Engines.—Take clearance every quarter.

Cylinders of Auxiliaries.—Open up and examine frequently and at least once a quarter. Take clearances of reciprocating engines.

Condensers.—Thoroughly examine and test every six months. Test for leaks and boil out with soda frequently.

Evaporators.—Scale every two weeks if running continuously.

Feed and Filter Tanks.—Clean out every three weeks.

Steam and Vacuum Gauges.—Test or compare every quarter.

Auxiliary Machinery.—Overhaul and examine every quarter; operate and test at least once a quarter.

Pumps, Air.—Overhaul and examine thoroughly at least once a quarter.

Pumps, Circulating.—Overhaul thoroughly at least once a quarter. Try on drainage system once every month.

Pumps, Main Feed.—Overhaul thoroughly at least once a quarter.

Pumps, All Other.—Overhaul thoroughly at least once a quarter.

Propellers.—Examine at least every three months after being out of dock.

Examine before going to sea. [*Art. 1640, Par. 7, N. R.*]

Strainers on Sea Chests.—Examine and clean by divers at least every three months after being out of dock.

Valves, Main Engines.—Examine after runs and at least once a quarter. Setting to be verified every six months.

Valves, Auxiliary Engines.—Examine frequently and at least once a quarter.

Valves in Manifolds.—Examine at least once a quarter.

Valves in Steam and Exhaust Line.—To be ground in or examined at least once in six months.

Valves, Safety.—Test every month. Try gear every week.

Valves, Stop.—Work every week. Test gear.

Valves, Sluice.—Work every week.

INSPECTIONS.

Monthly Inspection.—The Executive Officer and the Senior Engineer shall each inspect monthly all compartments, watertight doors, and mechanical devices, for the management and safety of the vessel for which each is especially responsible, and shall make to the captain, after each inspection, separate written reports of the condition of the parts of the ship and of the mechanical devices thus inspected. [*Art. 1637, N. R.*]

Weekly Inspection.—Watertight doors, cocks, valves, ventilating appliances, pumps, watertight compartments.

[*Art. 396, Par. 5, N. R.*]

PART IV.

GENERAL ENGINEERING RULES AND REGULATIONS.

Directions contained in Navy Regulations, 1900, are noted by article and paragraph. Other directions do not have this reference, and are in general due to late improvements in machinery.

MAIN ENGINES.

Warming up Engines.—The cylinders, receivers and steam jackets must be gradually and thoroughly heated by opening connections between the boilers and engines as soon as fires are lighted and before steam of full pressure is admitted to them. The greatest care must be exercised that "water rams" are guarded against by carefully draining all pipes while raising steam. [*Art. 1606, Par. 1, N. R.*]

Water.—Water must not be allowed to accumulate in the jackets or receivers, but care shall be taken that steam is not being blown through the traps. [*Art. 1606, Par. 2, N. R.*]

Adjustment of Links.—Every opportunity shall be used to ascertain the proper grades of expansion in each cylinder for different powers; the powers developed in each cylinder should be equal, or nearly so, and when the proper points are ascertained a careful record must be made in the senior engineer officer's remark book for reference when changes in speed or power are required. [*Art. 1606, Par. 3, N. R.*]

Steam Pressure.—The steam pressure should be regulated so that the drop from steam pipe to point of cut-off is not excessive. To obtain economical results the steam should follow at nearly full boiler pressure to point of cut-off. At low speeds the boiler pressure should be lowered to suit the number of revolutions. The pressure, however, should not be reduced to such a degree that engines can not be readily handled.

Indicators.—The indicators shall not be allowed to remain attached to the cylinder when not wanted for immediate use; and they shall be dried, cleaned and lightly lubricated with cylinder oil before being put away. [*Art. 1606, Par. 4, N. R.*]

Examination of Cylinders.—The cylinders, piston rings, piston

springs, followers and follower bolts shall be frequently examined and their condition noted in the steam log.

[*Art. 1606, Par. 8, N. R.*]

Moving Machinery.—When not under steam, the engines and main valves are to be moved every day, when possible, and all steam machinery jacked at frequent intervals, the fact being noted in the steam log. [*Art. 1606, Par. 10, N. R.*]

Holding-down Bolts, etc.—All holding-down bolts shall be examined at least once in three months, and care taken that the nuts of pillow block bolts do not become set fast. The clutch couplings shall be moved and lubricated once a day when not under steam. [*Art. 1606, Par. 12, N. R.*]

Hatch Gratings.—The gratings over the engine-room hatches are not to be taken off, except in cases of necessity, and shall be replaced as soon as possible. [*Art. 1606, Par. 13, N. R.*]

Cylinders Opened After Run.—As soon as practicable after each run, the manhole plates on cylinder heads will be removed and the interior of cylinders cleaned and covered with a thin coating of oil or vaseline. [*Art. 1606, Par. 16, N. R.*]

Arrival in Port.—On arrival in port the engines should be wiped down and cleaned, and every effort made and facility utilized for overhauling and remedying defects, adjusting and placing machinery in efficient steaming condition.

Stuffing Boxes.—When stuffing boxes have been packed with soft packing care should be taken not to set up the packing too tightly, and, when steam is admitted, small leaks should be stopped gradually, so that the packing may expand.

Use of Bleeders.—When bleeder valves are fitted on the condensers they should be used with great caution, as a sudden rush of steam may cause injury to the tubes or condenser shell.

Oiling Gear.—After every run the oiling gear and water service should be thoroughly cleaned, and any defects in pipes, etc., remedied. The wicks should be kept in proper condition and changed as to size to accommodate different conditions and variations in temperature, since oil runs more freely in warm than in cold weather.

Pistons, Clearance of.—The clearance of pistons should be frequently examined by measuring the distance that piston is from striking points when engines are on top and bottom centers. This must be done at least once each quarter, and the location of striking points should be verified by disconnecting crosshead and moving piston till it strikes bottom and top of cylinder.

Valves, Setting of.—The setting of valves should be verified from time to time, and adjusted so that the cut-off and lead are alike for both ends. Whenever the indicator diagrams show an improper setting of valves, the first opportunity must be taken to correct this.

Bearings.—Water should not be used unnecessarily on the bearings, and when it is used care will be taken that it is discontinued a sufficient length of time before engines are stopped, to allow the lubricating oil to find its way to all parts of the surfaces of the journals.

When water has been used on a bearing, the bearing shall be examined at the earliest opportunity. [*Art. 1607, N. R.*]

CONDENSERS AND HOTWELLS.

Examination of Tubes.—The tubes of surface condensers must be examined at least once in six months and kept clean. If not examined, the reasons for the omission are to be stated in the quarterly report. If any considerable amount of steaming has been done, the condensers must be examined before the expiration of the time mentioned. [*Art. 1608, Par. 1, N. R.*]

Leaky Condenser.—If at any time the condenser tubes are found to be leaking, steps will be taken, as soon as the engines are stopped, to prevent the passage of water from the condensers to the cylinders. [*Art. 1608, Par. 2, N. R.*]

Salt Leaks.—Should there be any indication of salt feed, the condensers should be tested at the first opportunity and salt leaks stopped by every means available.

Boiling Out.—Condensers should be frequently boiled out with soda and steam to remove all deposit on tubes. This should be done at least once every six months.

AIR AND CIRCULATING PUMPS.

Starting Before Moving Engines.—Independent air and circulating pumps will be started at least fifteen minutes before attempting to move the engines or to warm the cylinders by means of the pass-over valves. [*Art. 1608, Par. 4, N. R.*]

Valves Examined.—The valves of air and circulating pumps shall be examined frequently. [*Art. 1608, Par. 6, N. R.*]

Cleaning and Repairs.—The valve seats of pumps must be frequently cleaned of grease, valve springs examined and renewed and plungers packed.

FEED PUMPS.

Use of Feed Pumps.—The boiler feed pumps shall not be used for other purposes than those connected with their special service, except in cases of emergency; and, when not under steam, their pistons and valve gear must be moved every day and the cylinders kept well oiled. [*Art. 1608, Par. 7, N. R.*]

Use of Feed Pump having Salt Connection.—The preservation of fresh feed water is of the utmost importance to the keeping of boiler in an efficient state. To this end the pumps used for feeding boilers should, except in cases of absolute necessity, be those having only fresh-water connections. Whenever a pump having salt or bilge connection is used for feeding boilers, it should be carefully noted in the log, and special precautions should be taken to see that sea or bilge valves are properly closed and that the pump has been washed out by pumping a number of strokes overboard.

EVAPORATORS.

Examination.—The interiors of evaporators shall be frequently examined and the tubes or coils cleaned and scaled when necessary. [*Art. 1608, Par. 8, N. R.*]

Use of Zincs.—When evaporator tubes or coils are made of iron or steel, zinc plates shall be fitted for protectors, as in boilers. [*Art. 1608, Par. 9, N. R.*]

When Not in Use.—When an evaporator will not be required for use for several days, the shell and coils shall be drained and kept dry till needed for service. [*Art. 1608, Par. 10, N. R.*]

Scaling.—Evaporators should be, as far as possible, in continual operation, as this will lessen wear, tear and corrosion. With continuous running they should be scaled about once in fourteen days. In scaling, special precaution should be taken that particles of scale do not get into wearing parts of machinery. It is advisable to fit zincs, even if steam head and tubes are made of composition.

OIL AND LUBRICATION.

Prohibition of Tallow and Certain Oils.—No tallow nor oil of vegetable or animal origin shall be used for the lubrication of cylinders and valves, but mineral oil only shall be employed. [*Art. 1606, Par. 5, N. R.*]

Quantity for Internal Lubrication.—As little oil as possible shall be used for interior lubrication; this prohibition is intended to apply to every steam cylinder in the ship, for whatever purpose intended. [*Art. 1606, Par. 6, N. R.*]

No other oil should be used for internal lubrication than that used for swabbing rods and for oiling parts when taken apart at overhaul and examination. When, by extreme necessity, valve gears of pumps require oil for their operation, only the smallest quantity should be introduced, and in these cases it is preferable to remove the valve gear and wipe off moving parts with kerosene and mineral oil, adding a small quantity of graphite.

Lubrication of Rods.—Care must be taken that the oil used for lubricating the rods is not drawn into cylinders in which there may be a partial vacuum. [*Art. 1606, Par. 7, N. R.*]

(This applies particularly to dynamo engines and blowers.)

Use of Filters and Grease Extractors.—When filters or grease extractors are fitted, they must be used, except when under repairs or being cleaned. [*Art. 1608, Par. 5, N. R.*]

Selection and Use of Oil.—Special precautions should be taken to secure proper oil for lubricating purposes. If possible, those oils only should be selected that are furnished from reliable and well-known sources.

Oil taken from crank pits and filtered should be used only for purposes in connection with the preservation of machinery.

Special care will be taken to prevent the mixture of vegetable oil with water or mineral oil.

Oil used for oiling worm gears, hinges, clamps, threads, etc., should be heavy mineral oil mixed with graphite.

VALVES AND COCKS.

Valves and Cocks, Grinding In.—Special care should be taken to keep all cocks and valves tight. They should be frequently examined and ground in when necessary.

Operation Weekly.—All cocks and valves throughout the engineer department are to be moved at least once each week.

[*Art. 1606, Par. 9, N. R.*]

JOINTS IN PIPING.

Leaks.—Special attention should be given to securing the tightness of all steam joints; leaks should be remedied at the earliest opportunity, as the loss of fresh water and waste of heat through leakage may, with high-pressure steam, amount to a very large percentage.

Setting Up on Nuts.—Nuts on flanges of joints under steam pressure should not be set up too tight when hot, since, when they cool and contract, a great strain is brought upon the bolts.

BILGES AND COMPARTMENTS.

Hatch Gratings.—The gratings over the engine-room hatches are not to be taken off, except in case of necessity, and shall be replaced as soon as possible. [*Art. 1606, Par. 13, N. R.*]

Rubber Gaskets.—The rubber gaskets of watertight doors, manholes, hatches, air ports, etc., must be neither painted, greased, nor oiled; louvres, gauze air screens, screw threads, and zinc protectors on the bottom must not be painted.

[*Art. 1640, Par. 4, N. R.*]

Debris.—Great care must be observed that no loose articles of copper or bronze, filings of the same, or rust scale, are allowed to rest on the bottom in immediate contact with the iron or steel, and that the leaden pipes, strainers, or such other parts in the bilges are kept in good condition. [*Art. 1640, Par. 6, N. R.*]

Lights.—An incandescent electric lamp of high power, with a portable connection, shall be used for examiring the condition of double bottoms, the interiors of boilers, and other dark places. [*Art. 1640, Par. 9, N. R.*]

Precautions on Examinations.—When about to examine, clean, or paint double bottoms or boilers, the following cautionary measures must be adopted: They should be opened up and well ventilated, a connection being made to a fan system if possible. This done, the purity of the air should be tested before entering by burning a candle on the bottom at least five minutes. Working parties inside must always maintain communication with some one outside; they must also have with them a lighted candle, and withdraw should it begin to burn dimly.

[*Art. 1640, Par. 10, N. R.*]

Water in Double Bottoms.—The double bottoms of iron and steel ships may be utilized for carrying fresh water for steaming purposes whenever, in the opinion of the captain, it is desirable. Under ordinary service conditions the double bottoms should be kept free from water. When salt water is admitted to the double bottoms of a ship in commission, either purposely or accidentally, the captain shall, as soon as practicable, report the fact and the accompanying circumstances to the Department.

[*Art. 1641, N. R.*]

Valves of Sounding Pipes.—Valves of sounding pipes to double bottoms must be kept closed when not in use. The height of the water in the bilges will be measured, and all bilge and crank-pin strainers cleaned each watch. [*Art. 1608, Par. 3, N. R.*]

Painting.—All paint work about the engineer department shall, if practicable, be white. [*Art. 1617, N. R.*]

Red Lead.—Should red lead be used at any time for painting the double bottoms or other confined spaces in the engineer department, the Senior Engineer Officer will see that proper precautions are taken to prevent its injurious effects on the health of the men. Two days is the maximum length of time that a man should be kept at this work. [*Art. 1617, N. R.*]

Waste Material—Cotton waste or any other materials used for wiping, and which are saturated with oil, will be destroyed im-

mediately after using, or, if intended for starting fires, will be put in a covered iron receptacle, and the latter kept in a safe place. [*Art.* 1618, *N. R.*]

HYDRAULIC MACHINERY.

The hydraulic pumps, engines, pipes and the gear connected therewith will frequently be examined, kept in good order and clear of water when not being worked.

The hydraulic engines will be moved at least twice a month by means of the pumps fitted for that purpose, to prevent the rams becoming set and to insure their efficiency.

When water must necessarily remain in the pipes, the aircocks will be left open; stoves will be used if there is any danger of freezing. [*Art.* 1623, *N. R.*]

AIR COMPRESSORS.

After using air-comrpessing machinery, great care will be taken to see that the engines, pumps, separators, charging columns and reservoirs are blown out and well drained.

A spare set of cup washers will always be kept ready for immediate use.

All parts of machinery subject to pressure will be tested to the full pressure once each year and the fact noted in the steam log.

The oil for lubricating the internal parts will be neatsfoot when the cups are of leather, or, if that cannot be obtained, other animal oils or castor oil will be used.

Cup leather washers must be kept in tins filled with castor oil.

Distilled water should be used for lubricating the internal parts of the pumps, if it can be obtained; water containing lime must not be used.

Owing to the small clearances allowed in air-compressor pumps, great care must be used in adjusting the bearings.

[*Art.* 1622, *N. R.*]

BOILERS.

Reports of Condition—Special mention shall be made in the quarterly reports of the condition of the boilers and the means which have been employed for their preservation.

[*Art.* 1609, *Par.* 1, *N. R.*]

Periodical Examinations.—The boilers shall be thoroughly examined at regular intervals of about three months; other examinations being made as opportunity offers and as the senior engineer officer may consider necessary. A detailed description of the condition of each boiler at each of these examinations shall be entered in the steam log and the senior engineer officer's remark book.

If anything should occur to prevent these periodical examinations, the causes will be fully stated in the steam log.

[*Art.* 1614, *N. R.*]

Drill Tests.—When, during the periodical examinations of boilers, the senior engineer has reason to believe that any part or parts of the boiler are unduly worn or corroded, he will cause these parts to be tested by drilling, the holes to be not over one-half inch in diameter. The thickness of the plates originally and when drill tested, the probable cause of corrosion or wear, and all other details of the test will be entered in the steam log and senior engineer officer's remark book. [*Art.* 1615, *N. R.*]

Should a drill test (*Art. 1615*) be made and reveal unusual thinness of any plates, the water pressure will be very carefully applied, in order that injury may not be caused by over pressure.

[*Art.* 1612, *Par.* 5, *N. R.*]

Hydraulic Test.—The boilers of all vessels in commission shall be tested by water pressure at such times as the senior engineer officer may deem necessary or advisable.

The test water pressure applied to boilers shall not exceed the designed working pressure plus 25 per cent. of same when the boilers have been in service longer than two years.

During the application of water pressure the boilers will be carefully examined and proper gauges used to detect any change in the form of any of their parts.

In applying water pressure care must be taken that there is no leak past the main or auxiliary stop valves. [*Art.* 1612, *N. R.*]

Record of Tests.—The following particulars of the results of boiler tests will be entered in the steam log and the senior engineer officer's remark book: The greatest pressure applied, the load per square inch on safety valves previous to the test and

when boilers were first used, the date of last repair, the length of service for which the boilers were repaired; the effect of the test on the plates and stays of furnaces, combustion chambers and shell, and on the tube sheets; the estimated durability of the boilers with such repairs as can be made by the force on board, and such additional information as may be considered necessary to enable a more complete estimate to be formed of the condition of the boiler. [*Art. 1613, N. R.*]

FEED WATER.

Filling Boilers.—The boilers will always be filled with fresh water when possible. When filled from overboard, the necessity for doing so from shallow water or using impure water of any kind should, as far as possible, be avoided. [*Art. 1609, Par 13, N. R.*]

Changing Water.—The water will be retained in the boilers without change as long as possible, even when the fires are not lighted. The boiler will be drained only when necessary for examination, cleaning or repairs, and the water changed only when dirty or acid, or when the boiler is to be used for distilling without the aid of an evaporator. [*Art. 1609, Par. 14, N. R.*]

Use as Tanks; Washing Out.—The boilers shall not be used for trimming ship nor for water tanks for any purpose, except for a reserve of fresh water when steaming in free route. Salt water shall never be introduced into the boilers except for the purpose of washing out the interiors or to make up a deficiency of feed when steaming when the supply of fresh water is not sufficient, or, as permitted in Paragraph 8 of this Article. When the interior of a boiler has been washed out with salt water, it shall be filled with fresh water immediately thereafter, or if fresh, water is unobtainable, with salt water. [*Art. 1609, Par. 15, N. R.*]

Acidity of Water.—In order to determine the condition of the water in the boilers as regards its acidity, neutrality or alkalinity, the water in each boiler will be tested with both kinds of litmus paper at least once per day when they are under steam, and once per week when the fires are not lighted. [*Art. 1610, Par. 1, N. R.*]

Litmus Test.—If the water in the boilers, on applying litmus paper, be in an acid condition, a small quantity of soda will be put into the condensers or hotwells, from which it will be

pumped into the boilers with the feed water. If the water in any one boiler shows acid properties, a solution of soda will be injected into that boiler. Only the smallest quantity of soda possible to accomplish the purpose intended shall be used.

[*Art. 1610, Par. 2, N. R.*]

Level of Water Line.—When water is used from a boiler, the water line must not be maintained at a level among the tubes.

[*Art. 1609, Par. 9, N. R.*]

Feed and Filter Tanks.—Feed and filter tanks should be frequently cleaned and filtering material renewed. The filter bed should be cleaned at least every twenty-one days. Grease extractors, when fitted, must be used and frequently overhauled to ensure their efficient working. Grease extractors are not efficient unless cleaned about once a week.

Air in Feed Water.—Special precaution should be taken to prevent air entering feed water.

Temperature of Feed.—The temperature of feed water should be maintained as high as possible, and feed heaters, when fitted, should be used on all occasions.

Grease Extractors.—When filters or grease extractors are fitted, they must be used except when under repairs or being cleaned.

[*Art. 1608, Par. 5, N. R.*]

OPERATION OF BOILERS.

Distribution of Work.—As in ordinary cruising it is usually necessary to use only part of the boilers, the work will be distributed equally among the different boilers. If any peculiarity of fitting or other cause prevents this distribution, the fact must be stated in the quarterly report of the log.

[*Art. 1609, Par. 31, N. R.*]

Services of deck force for Firemen and Coal Passers.

[*Art. 1197, N. R.* See *Sec. 1570, R. S.*]

Increasing Speed.—When it is necessary to increase the speed of a vessel having cylindrical fire-tube boilers, it shall be done (except in case of emergency) by increasing the number of boilers in use, under natural draft, until the entire number on board are in use, if requisite. [*Art. 1609, Par. 27, N. R.*]

(Note.—This rule does not apply to water-tube boilers.)

Changes in Temperature.—Sudden changes of temperature in the boilers are to be avoided; and when circumstances will permit, at least six hours should be occupied in raising steam from cold water. [*Art.* 1609, *Par.* 17, *N. R.*]

(Note.—This is intended for Scotch boilers.)

Coal in Firerooms.—Coal must not be stowed in the firerooms in such quantities as to cover up the handles or wheels of valves, or to get into the bilges, thus choking up suctions and strainers and endangering the safety of the ship. [*Art.* 1609, *Par.* 33, *N. R.*]

Connection Doors.—Connection doors must not be used as dampers. [*Art.* 1609, *Par.* 18, *N. R.*]

Record of Time Fires are Lighted.—The number of hours each boiler has had fires under it since the ship was commissioned is to be stated in each quarterly report. [*Art.* 1609. *Par.* 20, *N. R.*]

Sweeping Tubes.—The boiler tubes and all other parts exposed to the action of the fire should be swept and thoroughly cleaned soon after the fires die out. When under steam, every effort should be made to keep all heating surfaces free from soot.

Tube for Drawing Ashes.—Care should be taken that the tube for drawing the ashes from the combustion chamber, in boilers so fitted, is kept closed when fires are burning in the furnaces.

Cleaning of Fires.—Under ordinary conditions the fires must be cleaned at least once in twelve hours, each watch cleaning one-third the number of fires, the cleaning to be distributed through the watch, so that the formation of steam may not be unduly checked at any one time.

Use of Hydrokineters.—When practicable the hydrokineters, or other circulating apparatus, should be employed when steam is to be raised on boilers.

Coaling of Fires.—To insure a uniform condition of the fires the furnaces should be coaled at regular intervals, and, if possible, no more than one fire door is to be opened at one time.

Thickness of Fires.—Fires should be carried from 6 inches to 10 inches thick, depending on output and on character of coal. Special attention should be paid to keep fire level and to prevent choking at front.

Blowing to Discharge Sediment.—Water-tube boilers should be

given a slight bottom blow every day in order to rid boiler of sediment.

Surface Blow.—The surface blow of boilers should be frequently used to rid boilers of an accumulation of air and oil on the surface.

Gauge Cocks.—Gauge cocks should be blown through each watch to prevent their being stopped up with salt. The water columns should be tested at intervals by the double shut off method and the glasses kept clean.

Banked Fires.—Heavy banked fires should never be kept except in cases of emergency, but when so banked ash-pan doors shall not be put in place. [*Art.* 1611, *N. R.*]

Whenever it becomes necessary to keep light banked fires in horizontal and fire-tubular boilers, they must be pushed back about a foot from the furnace dead plates, covered with dampened coal or ashes, the ash-pan doors put in place, and the fires shaken down or cleaned once in twelve hours.

Hauling Fires after Steaming.—Fires shall not be hauled after discontinuing steaming, except in case of emergency, but shall be allowed to burn down and die out in the furnaces, with the dampers, furnaces and ash pits closed. The boilers shall not be blown down; when it is required to empty them, the water shall be pumped out. [*Art.* 1609, *Par.* 21, *N. R.*]

CLEANING AND CARE OF BOILERS.

After Run.—After every run when fires are hauled or allowed to die out, the fire sides of boiler must be immediately cleaned and put in an efficient state for steaming.

Deposit of Ashes or Soot.—Special precaution should be taken not to allow a deposit of moist soot or ashes to accumulate or remain on tubes or heating surfaces, and that all parts of heating surface are kept dry.

Cleaning Interior.—The water-washed heating surface of water-tube boilers should be frequently examined, and when the presence of scale or deposit exhibits itself, means should be taken for its removal. The interior of tubes should be thoroughly cleaned at least once every six months.

Dry Pipes and Drains.—The dry pipes and drains of the steam drums are to be examined frequently, to ascertain if the holes in them are clear. [*Art. 1609, Par. 6, N. R.*]

Priming Furnaces.—When boilers are empty the furnaces shall not be primed. [*Art. 1609, Par. 10, N. R.*]

Securing Valves.—The main and auxiliary stop valves, safety, check and blow valves, and any other valve or cock by which steam or hot water could enter the boilers in which men are at work, will be shut and secured, so that they cannot accidently open or be opened. The engineer officer having the day's duty will see that these precautions are carried out before he allows any men to enter the boilers *Art. 1609, Par. 11, N. R.*]

Lifting Safety Valves.—The safety valves will be partially lifted by the hand gear at least once each week when not under steam, to insure their good working order. [*Art. 1609, Par. 12, N. R.*]

Care of Exterior.—The exteriors are to be kept as dry as possible, and nothing wet or combustible is to be stowed over or around them. The bilges in the firerooms are to be kept dry and well painted. [*Art. 1609, Par. 16, N. R.*]

Care of Uptakes.—The uptakes shall be kept free from dirt and well painted. [*Art. 1609, Par. 19, N. R.*]

Air Space in Uptake.—The air space between the uptake and casings of the boilers shall be examined frequently, and any accumulation of soot or coal dust prevented.

[*Art. 1609, Par. 30, N. R.*]

Ashes in Firerooms.—When it is necessary to keep ashes in the firerooms until a lighter can be obtained, they must not be stowed against any part of the boilers or bulkheads; boards or heavy canvas must be used to protect the metal surfaces.

[*Art. 1609, Par. 32, N. R.*]

Care of Forced-Draft Ducts.—The thin sheet-iron bulkheads of air ducts of the forced-draft system must be kept free from ashes and rust and well painted. [*Art. 1609, Par. 34, N. R.*]

Boiler Interiors When Not in Use.—The boilers when empty are to be kept dry by such means as are at the disposal of the officer in charge. The water bottoms and lower part of the fronts are to be kept free from scale and rust and contact with ashes, and well painted. [*Art. 1609, Par. 7, N. R.*]

Boilers that are not in use should be kept, if possible, full of fresh water made slightly alkaline, and, failing in this, full of salt water made slightly alkaline. [*Art. 1609, Par. 8, N. R.*]

When coil, pipe or water-tube boilers are not in use for steaming purposes their interiors shall, if possible, be kept perfectly dry; their exteriors shall also be kept dry, and, where accessible, well painted with metallic paint. [*Art. 1609, Par. 22, N. R.*]

If for any cause, such as a leaky valve, it is impossible to keep the interiors of coil, pipe or water-tube boilers perfectly dry when not in use for steaming purposes, boilers of this class shall, till such cause can be removed, or the boilers are required for steaming purposes, be kept filled to their highest point with fresh water made slightly alkaline. [*Art. 1609, Par. 23, N. R.*]

As it is generally extremely difficult to keep boilers dry, the safest practice is to keep them completely filled with fresh water, care being taken to exclude all air by allowing a slight pressure to come on boiler and opening safety valve or air cock. This should be done as soon as boiler is cool, and IN NO CASE should water-tube boilers be allowed to stand for more than a few hours with boilers partly filled.

Drying Fires.—Light fires should occasionally be made in drying stoves placed in the ash pits of coil, pipe or water-tube boilers not in use, in order to dispel moisture.

Forced Draft.—Forced draft shall not be used on cylindrical fire-tube boilers except in emergencies and during the power trials specified in Article 1603. [*Art. 1609, Par. 26, N. R.*]

Blowers for Ventilation or to Assist Draft.—The blowers may be run at any time at moderate speed, for purposes of ventilation or to assist the draft, but the air pressure must not exceed one-half inch of water. [*Art. 1609, Par. 28, N. R.*]

PREVENTION OF CORROSION.

Use of Zincs.—Zinc slabs shall be suspended in such parts of the boilers as may be directed by the Bureau of Steam Engineering. The senior engineer officer on each inspection of the boilers shall examine these zincs and note their condition in the log. To make the zincs efficacious, special care must be taken

to insure perfect metallic contact between the zincs and the stays or plates of the boilers to which they are attached, the surfaces in contact being filed bright. [*Art. 1609, Par. 2, N. R.*]

Slabs or rolled zinc will be used, these being renewed as soon as the exposed surface is reduced by oxidation to about half the original area. Zincs that have become bent or distorted should, however, be removed at once as inefficient. Worn and defective zincs will not be recast for use on board. Should it be necessary to use slabs of cast zinc at any time, good material only shall be used. [*Art. 1609, Par. 3, N. R.*]

It has been found by experience that the number of zinc slabs (twelve by six by one inch) required for the thorough preservation of boilers is about one for every fifty square feet of tube surface; that is, approximately equal to $\frac{N \times D \times L}{197}$, where N is the number of tubes plus the number of solid stays fitted in lieu of stay tubes, L the length between tube plates in feet, and D the external diameter of tube in inches. When the number has not otherwise been determined by the Bureau of Steam Engineering, this will be the proportion used. This proportion is, however, merely intended as a guide, and not to interfere with any alteration of position or number which may appear desirable or necessary for the arrest of oxidation. About one sixth of the whole number of slabs should be put in the steam spaces.

Art. 1609, Par. 4, N. R.]

Prohibition of Tallow and Vegetable Oil.—No tallow nor oil of vegetable or animal origin shall be allowed to enter the boilers. This prohibition applies to all boilers in use aboard ship of whatever type or service. *Art. 1609, Par. 5, N. R.*]

Air in Boilers.—The accumulation of air in interior of boilers should be guarded against by all possible means. In order to expel air, surface blow valves should be open at intervals, to expel air collected at surface of water.

Lime in Boilers.—Feeding of small quantities of milk of lime into boilers supplies a thin coating for the prevention of corrosion.

Boiling Out and Use of Soda.—Caustic soda should be fed

into boilers, especially water-tube boilers, in small quantities every few days in order to dissolve the oil and to maintain the water in an alkaline state. Water-tube boilers should be frequently boiled out with a strong solution of caustic soda in order to remove oil deposit.

Use of Kerosene.—In special cases for cleaning the interior of small-tube boilers kerosene may be used, but special precaution must be taken to wash out boiler thoroughly afterwards so that there is none remaining in boiler when steam is again gotten up.

COAL.

Description and Record.—Full information will be noted in the steam log of the kind, quality, steaming power, and other particulars of the coal received. The statement that the coal is bituminous or anthracite, being indefinite, will not be used except when it is impossible to obtain any further information of the coal received, in which case a special note of the fact will be entered in the steam log. [*Art. 1616, N. R.*]

Delivery.—Whenever coal is delivered on board a steamer, he (equipment officer) shall enter it with the invoice price on the equipment books and immediately expend it as transferred to the engineer department. [*Art. 568, N. R.*]

Precautions to be Taken Against Fire from Spontaneous Combustion and Coal Gas.—Except in emergencies coal should not be taken on board in a condition that might render it dangerous. The bunkers containing such coal should be carefully watched.

Coal, after having been received, should be kept as dry as possible. Special precautions should be taken to prevent the leakage of water into the bunkers.

Ventilation.—When coal bunkers are not provided with permanent ventilators, the plates should be removed for ventilation at least twice a week, and oftener if convenient, and kept removed for a period of several hours each time.

Coal Bags.—Coal bags that have been used should be examined periodically, as fine coal dust remaining in them may produce spontaneous combustion.

Examination of Bunkers.—Before coaling, he (senior engineer)

shall ascertain the condition of the bunkers and of all watertight openings; and shall satisfy himself that no unauthorized materials are stowed in the bunkers. [*Art. 662, Par. 2, N. R.*]

Ventilation.—The openings for coal-bunker ventilation should be examined frequently to guard against accidental closing or clogging. In good weather, deck-scuttle plates should be removed to ventilate the bunkers.

Amount on Hand.—He (senior engineer) shall frequently examine the coal bunkers with the view of ascertaining the quantity of coal actually on hand, as compared with the amount called for by the coal account. Should he discover any material excess or deficiency, he shall report it at once to the captain. [*Art. 662, Par. 1, N. R.*]

Coal-Bunker Bulkheads.—The interior surfaces of coal bunkers, being subject to excessive abrasion, are liable to rapid corrosion if not thoroughly protected. As far as practicable, they should be cleaned and painted with brown oxide of iron or with red lead at least once a quarter.

PROPELLERS

Propellers will be examined and cleaned of marine growth at least once every three months after vessel is out of dock.

Bronze propellers shall at all times before starting on a voyage, if possible, be cleaned of all marine growth. Zinc protectors must be placed near them. [*Art. 1640, Par. 7, N. R.*]

INJECTION STRAINERS.

Injection strainers should be blown out with steam after any considerable stay in port, but especially in tropical waters, where jelly fish and marine growth abound. Strainers should be cleaned by divers once in three months.

STEAM BOATS.

The preceding instructions for the management, care and preservation of the machinery of the vessel will, as far as applicable, govern the management, care and preservation of the machinery of the steam launches, pinnaces, etc.

The safety valves of the boilers of steam boats will be examined whenever steam is raised after an interval of more than

seven days not under steam. The condition of the safety valves, water gauges, check valves, etc., will be ascertained from time to time while the machinery is working. Great care will be taken to keep these important fittings in a thoroughly efficient condition.

Salt water will not be used in the boilers of steam boats except in cases of great emergency, and after its use the boilers will be scaled and cleaned as soon as possible.

The time that steam boats have been under steam will be entered in the steam log.

Under no circumstances will the height of water in locomotive boilers be less than three inches over the crown sheets.

Unless it is expected that the machinery of steam boats will be used again in a few days, the wearing surfaces of cylinders and valve chests will be cleaned and lightly coated with mineral oil, and the engines made ready for use. All drain cocks should be kept open and the engines, valves, pumps, etc., moved every day.

Strainers on sea-valve openings for steam boats will be kept clear, and receiving pipes of circulating and air pumps examined and cleaned annually, or more frequently, if necessary.

The boilers of steam boats will be frequently examined, internally and externally. Especial attention will be paid to the furnace.

In boilers fitted with removable stays or braces, great care will be taken to replace them properly when they have been taken out. The boiler will be tested by hydraulic pressure after the stays have been replaced. The reasons for removing the stays and the result of the test will be entered in the steam log.

[*Art. 1620, N. R.*]

TORPEDO BOATS.

In consequence of the lightness of construction and the high speeds at which torpedo-boat engines run, increased care is necessary in attending to and adjusting the various working parts. Mineral oil only will be used in the cylinders, and that sparingly, and only at high speeds, as no lubricant is, as a rule, necessary at moderate speeds. Oil will not be put into the cylinders when it is probable that the engines will soon be stopped.

Vedette torpedo boats may continue to run at moderate speed

for at least thirty days without changing the water in the boiler. Should, however, a long run at high speed be anticipated, the boiler will be washed out and refilled before starting. With new boilers it may be necessary to change water several times until they are quite clean.

Vedette torpedo boats will be run for three hours, for the purpose of instruction of the men, once in each quarter.

[*Art. 1621, N. R.*]

RAMMING.

All chocks and ties fitted to cylinders, boilers and other parts of the machinery, to prevent their shifting from the effects of collision, will be kept at all times in an efficient condition, and they will be examined at least once each quarter, and their condition noted in the steam log.

Before going into action, all articles which might be thrown down or displaced by a collision will be secured or so disposed that no injury can be done to the machinery or to the officers and men in the Engineer Department.

When it is intended to ram, or when the vessel is likely to be rammed, notice will be given from deck to the Engineer Officer of the watch, through the speaking tube or by other prompt method of signalling, so that men, tools, etc., may not be thrown down or against moving parts of the machinery.

To prevent the passage of water from the boilers into the engines when the collision takes place, the separator will be emptied and its blow-off cock opened to the sea just before the shock is expected to take place. This cock may also be allowed to remain open until the engines are safely reversed.

A man will be stationed at each of the main stop valves to shut off any or all of the boilers, should it become necessary, and, in order to facilitate this, the valves will be screwed down as far as possible without reducing the steam required by the engines.

In ramming, being rammed, and generally in cases of collision, the men should go to their stations for starting all bilge pumps, bilge injectors, and other means provided for freeing the ship of water in case of dangerous leakage. [*Art. 1619, N. R.*]

SHIPS OUT OF COMMISSION.

When a ship is ordered out of commission, the iron or steel bright work of the machinery, except such parts as pass through stuffing boxes, or upon sliding surfaces (as piston rods, valve stems, slide and guide faces and journals), shall be covered with white lead and tallow, or vaseline.

Packing shall not be removed from piston rods or valve stems.

Wearing Metal Parts.—All parts passing through stuffing boxes or working upon their surfaces, such as piston rods, valve stems, guide and slide faces, clutch-coupling slides, interiors of steam cylinders and valve chests, must be cleaned and covered with a coating of vaseline, the machinery being moved after first application so as to bring all these parts upon properly covered surfaces.

Bearings.—All bearings must be well oiled and the oil holes plugged with waste, the engines being turned one complete revolution after oiling.

Water-Containing Parts.—All water-containing parts of the machinery inside of outboard valves must be thoroughly drained. Particular attention should be paid to draining of pump cylinders, condensers, feed, blow and suction pipes; fire main, and all steam and exhaust piping where it is possible for water to gather. In draining these pipes, flange joints should be broken at the lowest parts of each system and wherever a pocket is formed which is not drained by a proper drain pipe. Outboard valve casings below valve seats musts be covered where possible with non-conducting material, such as sawdust or manure, temporarily boxed in.

The gauges and oil cups will not be removed.

The sea valves must be closed and properly secured.

The storerooms must be cleaned. [*Art. 1624. N. R.*]

INDICATORS, CARDS AND HORSEPOWER.

Before taking cards, the pipes leading to the indicators will be cleared of water and the indicators cleaned and their pistons slightly lubricated with clean cylinder oil. The indicators must

not remain attached to the cylinders unless wanted again for immediate use. They will be dried and cleaned before they are put away.

Cards will be taken at least once a day if the engines are in operation for twelve or more hours consecutively.

Low Speeds.—It should be remembered that cards taken at low speeds are just as valuable for purposes of calculation of the efficiency of the ship and engines as those taken at high speeds.

Record.—A record of the cards taken will be kept on board, and the powers at all possible speeds will be obtained whenever opportunity offers.

The sets of indicator cards will be numbered consecutively for each quarter and put in the pockets provided in the back part of the smooth log. Original diagrams only will be put in the logs, in those sent to the Bureau as well as in those kept on board. All data on the indicator cards will be in ink. The top and bottom of the diagrams will be designated and the atmospheric line drawn. The slip will be calculated for the speed and revolutions given on the cards, and will be expressed in per cent. of the speed of screw.

Computation.—The horsepower will be computed for each end of the cylinder separately. The indicated horsepower entered in the Synopsis will be the average for the time specified, and not that developed at the time the cards were taken. This average power will be to that found from the cards in the proportion of the cube of the average revolutions for the specified time to the cube of the revolutions at the time the cards were taken, other things being equal. The power thus obtained will be entered in the appropriate column, and, with the addition of the power developed by or estimated for the air and circulating pumps and auxiliary machinery, will be used as the divisor in computing the number of pounds of coal per I.H.P. per hour, and as the numerator in computing the I.H.P. per square foot of heating surface.

Coal.—The amount of coal per hour, entered on the indicator

cards and in the forms, will be the net amount for all purposes, and not that given in the coal column of the log book.

[*General Directions, Steam Log.*]

GENERAL EXPLANATIONS AS TO NOMENCLATURE.

Engines.—1. In vessels having more than one propeller the engine turning the starboard propeller will be called the starboard engine; that turning the port propeller, the port engine; and that turning the middle propeller, the middle engine. They will be designated as the S., P. and M. engines, respectively.

Cylinders.—2. The cylinders of multiple-expansion engines will be called the high-pressure, intermediate-pressure and low-pressure cylinders, and will be designated by the letters H.P., I.P. and L. P., respectively. When there is more than one cylinder between the H.P. and L.P. cylinders the one receiving steam from the former will be designated as the 1st I.P. cylinder, the next one as the 2d I.P. cylinder, and so on.

Receivers.—3. Where there are two or more receivers the one nearest the H.P. cylinder will be called the first receiver and the next one the second, and so on.

Ends of Cylinders.—4. The end of the cylinder nearer the crank will be called the inboard and the other the outboard end.

Boilers.—5. Boilers will be lettered alphabetically (omitting J) and furnaces numbered.

In athwartship firerooms the letters will run, in each row of boilers, from starboard to port, beginning with A for the starboard forward boiler. The furnaces will be numbered from left to right for each boiler separately.

[*General Explanations, Steam Log.*]

WATCH QUARTER AND STATION BILL.

ENGINEER

First Section.

Number.	Rate allowed.	Rate actual.	Name.	Steaming station.	Repair station.	Cleaning station.	General quarters.	Fire or collision.	Gun or battery.	Abandon ship	Pay number.
	Ch. M.	Ch. M.									
6101	M. 1 Cl.	M. 1 Cl.			1 Cl. Petty Off.						
6106	M. 2 Cl.				2 Cl. Petty Off.						
6111	W. T.				Water Tender.						
6121	F. 1 Cl.				Firemen 1 Cl.						
6141	F. 2 Cl.				Fireman 2 Cl.						
6161	Coal P.				Coal Passers.						

Second

Number.	Rate allowed.	Rate actual.	Name.	Steaming station.
	Ch. M.	Ch. M.		
6201	M. 1 Cl.	M. 1 Cl.		
6206	M. 2 Cl.			
6211	W. T.			
6221	F. 1 Cl.			
6241	F. 2 Cl.			
6261	Coal P.			

U. S. S.....

DIVISION.

Section.								Third Section.												
Steaming station.	Repair station.	Cleaning station.	General quarters.	Fire or collision.	Gun or battery.	Abandon ship.	Pay number.	Number.	Rate allowed.	Rate actual.	Name.	Steaming station.	Repair station.	Cleaning station.	General quarters.	Fire or collision.	Gun or battery.	Abandon ship.	Pay number.
									Ch. M	Ch. M									
	1 Cl. Petty Off.							6301	M. 1 Cl.	M. 1 Cl.			1 Cl. Petty Off.						
	2 Cl. Petty Off.							6306	M. 2 Cl.				2 Cl. Petty Off.						
	Water Tenders							6311	W. T.				Water Tenders						
	Firemen 1 Cl.							6321	F. 1 Cl.				Firemen 1 Cl.						
	Firemen 2 Cl.							6341	F. 2 Cl				Firemen 2 Cl.						
	Coal Passers.							6361	Coal P				Coal Passers.						

GENERAL INSTRUCTIONS AS TO WATCH BILL.

All chief petty officers have letters instead of numbers.

Every number consists of four digits; the first number indicates the division, the second number the section, and the last two numbers the rate or group of ratings.

All numbers up to 20 are petty officers.

All petty officers first class, except water tenders, have number below 5.

All petty officers second class have numbers 6 to 10.

All water tenders have numbers 11 to 20.

All firemen first class have numbers 21 to 40.

All firemen second class have numbers 41 to 60.

All coal passers have numbers 61 to 99.

For water tenders, firemen and coal passers, the last digit of number indicates the number of fire room for steaming station.

Numbers ending in 9 and 0 have special stations, such as ice machines, storeroom, cooks, messengers.

Oilers and firemen first-class will be stationed at ice machine and evaporator.

Firemen first class or firemen second class will be stationed for storerooms.

Coal passers will be stationed as messengers and cooks.

Odd numbers belong to starboard side of vessel.

Even numbers belong to port side of vessel.

Cleaning and repair stations will be in general in the same compartment.

Names, actual rates and variable duties to be written in pencil so that changes can be made.

Numbers and duties should be written in ink to suit each individual ship.

LATEST TYPE OF BABCOCK & WILCOX MARINE BOILER.

SOME DETAILS OF THE DESIGN AND CONSTRUCTION.

By Lieutenant R. K. Crank, U. S. Navy, Member.

IMPROVEMENTS OVER THE OLD DESIGN.

The articles, descriptive and critical, on the Babcock & Wilcox Boiler, that have appeared in service publications, have referred generally to the older design of boiler, such as is installed in the U. S. S. *Marietta*. A number of changes have been introduced in the design of boiler for the new ships. The boilers of the armored cruiser *West Virginia* will be taken as the type for illustration and comparison.

A comparison of the *Marietta* boiler, Fig. 1, with the boiler of the *West Virginia*, Fig. 2, will show the following changes from the earlier design: ,

1. HAND-HOLE PLATES SUBSTITUTED FOR SCREWED PLUGS.

The screwed plugs of brass, that were fitted in the front headers of the *Marietta* boiler, one plug opposite the front end of each 2-inch and each 4-inch tube, to close the holes opposite the tube-ends, have been abandoned. Hand holes, closed by plates, have now been adopted, resulting in a very great improvement, as will be seen.

The 2-inch tubes are now arranged in rectangular groups of 4 tubes in a group. Opposite the ends of each of these groups of 2-inch tubes and opposite each end of each 4-inch tube is cut a hand-hole, about 5 inches by 5 inches, having the form of a rectangle with rounded corners. Around the periphery of this hole, inside the header, a machined face about $\frac{1}{4}$ inch in width is milled; this face is to receive the gasket by which the joint of the hand hole plate is made. A pressed-steel plate, similar in form to the hand hole and with a similar face milled for a

gasket around its periphery on one side, closes the hole. A threaded stud, 1 inch in diameter, projects from the center of this plate. The plate is drawn into place and held by a steel bridge and a nut that is screwed on the end of the stud, as shown in Fig. 3. The pressure in the boiler aids in holding the plate on its seat.

The oval hand holes and plates that, in the old design, were opposite the back ends of the tubes, have also been replaced by the rectangular hand hole and plate just described.

The advantages of the present hand hole over the tapped hole and screwed plug are manifest. The tapped holes and plugs, in which standard pipe threads were used, were slightly tapered, No two holes were tapped out to exactly the same extent, and a plug that made a tight joint in one hole would perhaps leak slightly when screwed into some other hole, just as the nuts holding a cylinder cover are not perfectly interchangeable. Hence, after having been taken out, for cleaning the tubes, the plugs might give considerable trouble through leakage when replaced, unless each plug were put back into its own original hole. Then, there were four plugs to be taken out where now there is only one easily removable plate. To clean a tube or to examine it through one of these small holes was difficult and annoying, and naturally also the thread of the hole was often damaged, and, moreover, a much longer time for cleaning or examination was required. Now, not only the tube, but the inner surface of the header may be quickly and easily inspected and cleaned. Any man of ordinary intelligence can take off and replace the hand hole plates in a comparatively short time.

The hand hole and plate above referred to were first used in working out the design of the boilers of the *Denver* class.

2. THE FORM OF THE HEADER CHANGED.

The form of the header has been changed, from the old sinusoidal form with easy curves, to the present form with flatter corrugations and more abrupt bends, as shown in the accompanying sketch Fig. 3. This change in the form of the header necesarily followed the change from screwed plugs to hand-holes and

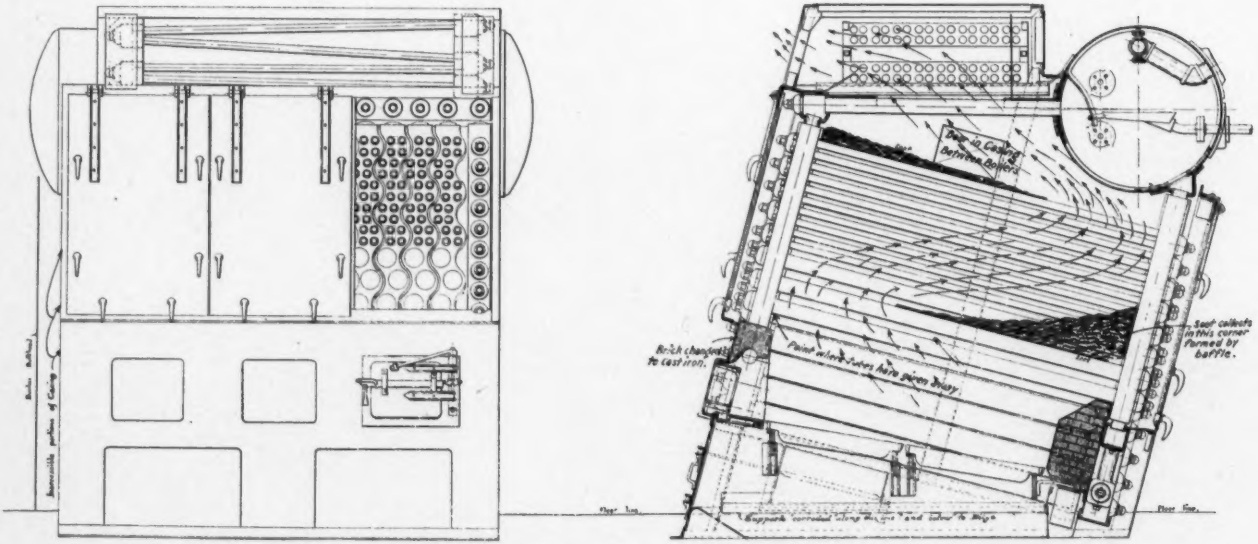


Fig. 1.--BOILERS OF U. S. S. "MARIETTA".

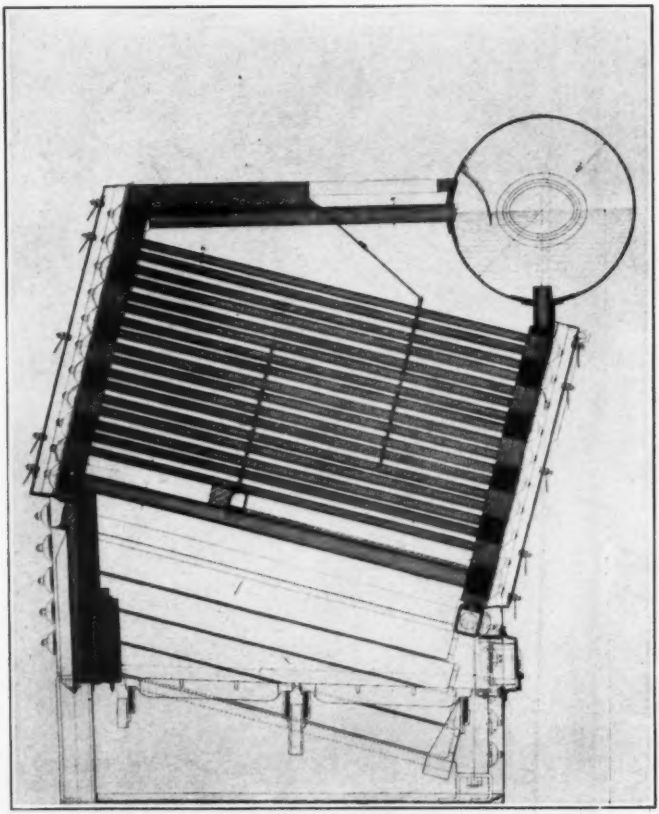


Fig. 2.—Side Elevation; Babcock & Wilcox Boiler, U. S. S. "West Virginia".

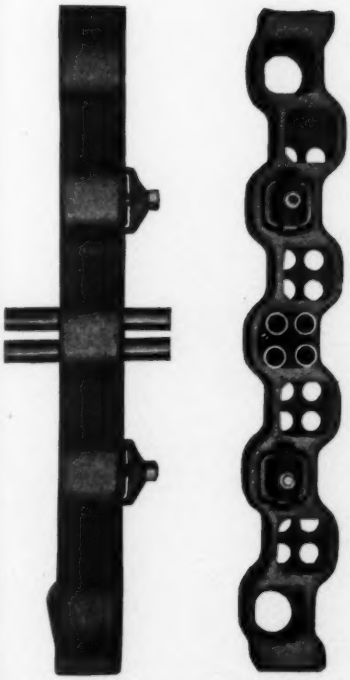


Fig. 3.—Forged-Steel Header; Handhole Covering Group of Four 2-Inch Tubes.

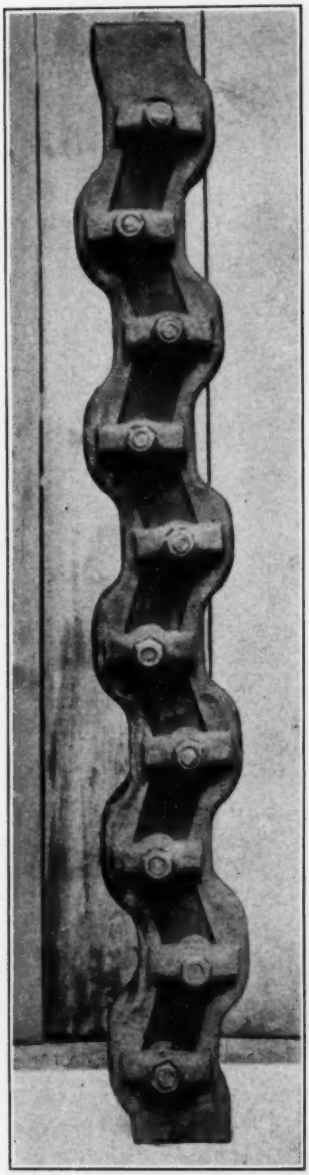


Fig. 9.—A Test Header; Bridges Cut Out.

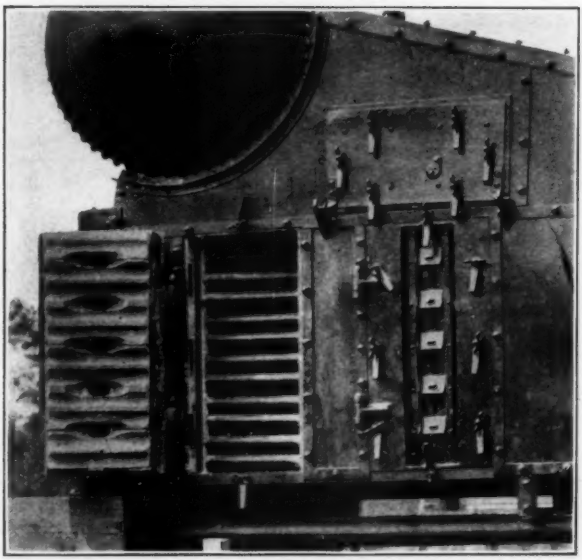


Fig. 4.—Cleaning Doors; Babcock & Wilcox Boiler.

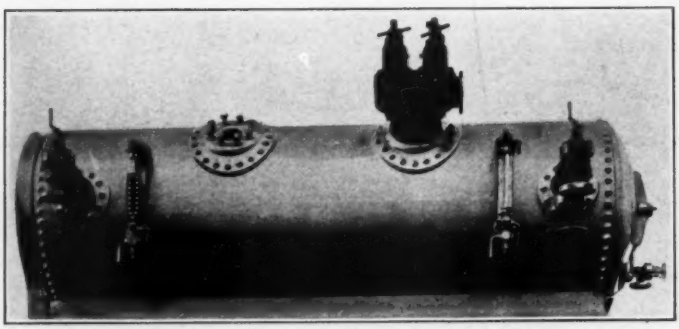


Fig. 7.—Drum Fittings, Exterior; Babcock & Wilcox Boiler.

plates, since, in order to have an opening opposite each group of 2-inch tubes of sufficient size to embrace the area covered by the group of tubes, it was necessary to adopt an opening of rectangular shape; and in order to cut such an opening of the required dimensions in the face of the header it became necessary to change the form of the header by making the front of the corrugations more nearly rectangular. With the present large opening the removal of a tube is very much easier than with the old style of plugs.

With the present form of header the tubes fall in horizontal rows, leaving horizontal "lanes" between rows of tubes for the insertion of the steam lance for blowing soot off the tubes, while, with the old form of header, the tubes fell, horizontally as well as vertically, in staggered rows. The sinuous "lanes" in a vertical direction, for the passage of the gases, were wider by about an inch than at present.

These new headers also were first used in the boilers for the *Denver* class.

3. FIRING-END OF BOILER REVERSED.

The boiler is now fired from the end opposite to that from which it was formerly fired; that is, the drum is now over the front or firing end of the boiler instead of over the back end. As will be seen from Fig. 1, in the boilers of the *Marietta* the drum is over the back of the furnace, and the grate has a very considerable inclination from the front to the back of the furnace, probably in order to get sufficient height of furnace at the back. The later design gives a much greater height of furnace at the back, where it is most needed, and permits the grate to be made horizontal, or nearly so. Partially as a result of this change the new system of baffling was introduced. Also, as a result, the position of the drum with reference to the headers underneath it was changed, so that the axis of the drum now comes directly over the top of the front headers. This change in the position of the drum tends to make the over-all height of the boiler somewhat greater; but it brings all the valves, water gauges, etc., in a position where they are easy of access and within the sight of the water tender. The steel box riveted along the bottom of the

drum (see sketch of the *Marietta's* boiler), into which the bottom nipples of the drum were expanded, is no longer necessary, as the drum is now in such a position that the nipples are expanded directly in holes in the bottom of the drum. The back ends of the tubes are now more accessible with the drum in front. This change was introduced first in the boilers of the *Atlanta* and the *Alert.*

4. CHANGE IN THE SIDE SECTIONS.

The straight side sections, which in the boilers of the *Marietta* are built of straight headers and 4-inch tubes and in the boilers of the *Alert* of straight headers and 2-inch tubes, have been replaced with side sections built of staggered headers and 2-inch tubes. One-half of the tubes in the outstanding corrugations of the header are left out in order to give a nearly straight, flat surface of tubes against which to build the side-casing. A comparison of the front elevation of the *Marietta* boiler and that of the latest type will show that, as a result of this modification, the vertical "lane" between the side, or outermost section and the section next inside it, through which, though baffled, the gases and products of combustion could escape from the furnace, is avoided, a slight increase in economy and efficiency being the result. This change was first introduced in the boilers of the *Cincinnati.*

5. THE REAR UPPER CROSS BOX DONE AWAY WITH.

The rear (upper) cross box, which ran across the tops of the rear headers (see Fig. 1, *Marietta* boiler) and served to connect the rear headers with the circulating tubes from the drum, is no longer used, except in special cases; instead, the rear headers have been made higher by one corrugation, and the front face of the header has been bumped out in this corrugation to the proper angle to receive the end of the 4-inch circulating tube from the drum. This is a simplification of design, and does away with all the nipples that were necessary at the tops of the rear headers.

This change was first made in the boilers of the *Wyoming* class.

6. IMPROVED METHOD OF BAFFLING THE GASES.

The old method of baffling the gases, by means of two baffles, one laid along the top of the uppermost row of 2-inch tubes and the other along the top of the second row of 4-inch tubes from the bottom, has given place to the improved method now used. In the latter there are also two baffles laid along on top of the tubes; one baffle is laid along the top of the 4-inch circulating tubes, between the drum and the tops of the rear headers and the other along the top of the lowermost row of 4-inch tubes just over the furnace. At the ends of these baffles and at right angles with them and with the tubes are placed two other baffles; these upright baffles fall roughly at points one-third the length from the ends of the tubes, as may be seen from the sketch of the *West Virginia's* boilers, The gases are thus made to cross the tubes three times on their passage to the uptake, and each portion of the tube does its share of work. With moderate forced draft the flame from the furnace generally goes as far as the middle of the second "pass." On the trial of the *Denver*, with 0.9-inch air pressure, the flame went into the third pass. The old system worked well at moderate powers; but when the boiler was forced the tendency was to drive the gases up through the straight "gut," and only the middle portion of the tubes did much work. A hot smoke pipe was generally the result. The new system gives greatly increased efficiency; while there is not the same tendency for the soot to accumulate unduly on the baffles laid along the tubes.

7. IMPROVED FACILITIES FOR CLEANING HEATING SURFACES.

The size and position of the cleaning openings in the casing have been changed—this partly as a result of the change in the method of baffling. There are now three large, upright doors in the side of the casing, swung on side hinges and easily opened; in the center of these doors are seven small openings, closed by a small, sliding shutter, through which a steam lance may be inserted for blowing off the outside of the tubes when under way. Below these three "dusting" doors are two long, narrow doors, held in place by latches, for cleaning the sooty accumulations

from the top of the lower baffle. Above these three doors and just back of the drum is another door for access to the space above the inclined tubes. These openings afford ample means of cleaning the heating surfaces, provided, of course, that sufficient room is always left between boilers at the sides to permit the free use of steam lance and soot hoe; they also facilitate the examination of outside of tubes and the use of brushes.

This arrangement is shown in Fig. 4.

8. TWO ROWS OF LOWER FOUR-INCH TUBES OMITTED.

Two of the three lower rows of 4-inch tubes that are fitted in the boilers of the *Marietta* have been omitted in the later designs, and in the place thereof two groups of 2-inch tubes put in. This leaves only one row of 4-inch tubes over the furnace, and along the top of this row the lower baffle is laid. This change gives more heating surface generally.

9. FEED-WATER HEATER DISCARDED.

The gain in economy from the use of the feed-water heater, placed in the hot gases of the uptakes, was more than offset by the trouble in keeping the heater in efficient condition. The corrosion of the heater tubes was excessive and the heater was inaccessible for attention and repair. In later machinery designs the same end is reached by installing a feed-water heater as an engine-room auxiliary, using the heat of the exhaust steam.

10. AN ADDITIONAL FOUR-INCH TUBE OVER THE FURNACE SIDE.

An additional 4-inch tube has been worked in over the four side boxes which form the water sides of the furnace. This tube is placed in the upper end of the vertical corner boxes. This addition makes the water side of the furnace more complete, increases slightly the heating surface, decreases radiation and does away with the tiling that was formerly necessary to fill in this space.

11. CROSS BEAM AT BACK OF BOILER INTRODUCED.

In the older design, the rear ends of the sections were unsupported from beneath and simply hung from the nipples that con-

nected the tops of the headers with the rear cross box. The ends of this cross box rested on top of the rear corner boxes. Now an I-beam, supported by brackets bolted to the rear corner boxes, takes the weight of the rear ends of the sections.

The front cross box, to which the lower ends of the front headers are connected, is supported by similar brackets bolted to the front corner boxes. The weight of the front ends of the sections is taken by the nipples connecting the tops of the front headers with the drum, and not by the cross box; the brackets supporting this cross box are put in merely for convenience in erecting the boiler.

12. VERTICAL HEADERS.

In the Babcock & Wilcox boilers of the *Chicago* and *Atlanta* the headers stand in a vertical position. The necessary inclination for the tubes (15 degrees) is obtained by bumping out the tube faces of the headers—a difficult and expensive process. With the headers vertical, the boilers would take up less floor space in the direction of the length of the tubes. This arrangement is shown in Fig. 5.

The changes enumerated above are the principal ones that had been made up to the time of the construction of the boilers of the *West Virginia*, although other changes have doubtless been made in the design of later boilers and in methods of manufacture.

It is the policy of the Babcock & Wilcox Company to make changes, regardless of the expense entailed thereby, whenever experience has demonstrated their advisability. In fact, it was the almost invariable experience of the writer, while on inspecting duty at the works of this Company, to find that any change in the design of the boiler which might suggest itself to him had already been "tried out" by the Company, and that a finished part embodying the suggested change might be found in what was known as the "museum."

This boiler is not the result of theory alone, but of many years of very expensive experiment and of actual trial and experience. This, in the opinion of the writer, is one of the greatest points in favor of the boiler.

Below is given a brief description of the details of design and

construction of some of the pressure parts and structural parts of the boiler, in the hope that it may be of some assistance to those who do not know the boiler well and who, nevertheless, may have to care for it.

STEAM AND WATER DRUMS.

Material.—For the boilers of the new ships, which are designed to carry a pressure of 265 pounds, the steam and water drums are made of open-hearth steel plate $\frac{21}{32}$ inch in thickness. The steel must conform to the specifications for *Class B* boiler plate of the Bureau of Steam Engineering specifications for material.

Shell.—(a) The cylindrical portion of the drum is made up of two plates, each $\frac{21}{32}$ inch in thickness. One of these plates is of such width as to extend around $\frac{3}{4}$ the circumference of the drum, the other plate around the remaining $\frac{1}{4}$ circumference. The butts of the plates are thus 90 degrees of arc apart. When the drum is in position in the boiler one butt falls vertically below the axis of the drum, the other butt, horizontally behind the axis of the drum. The reason for this and its advantage will be seen later.

(b) The plates are joined at the butts by double butt straps, also $\frac{21}{32}$ inch thick. Along the line of the butt, vertically below the axis of the drum, are cut the holes for the nipples that connect the tops of the front headers with the drum. Along the line of the other butt are cut the holes for the 4-inch circulating tubes that connect the tops of the rear headers with the drum. Thus one-half of each of these holes is cut from the edge of each shell-plate. The line through the centers of these holes is coincident with the center line of the butt straps.

(c) The holes through the butt straps for the nipples and for the circulating tubes are drilled accurately to a diameter of $4\frac{1}{32}$ inches. The holes in the edges of the shell plates are punched to a diameter of $4\frac{1}{4}$ inches. Thus the 4-inch tubes and nipples, when expanded, take against only the holes in the straps as shown in Fig. 6, bulging out slightly into the annular space between the straps. This gives a very strong, expanded joint, with a total bearing for each tube or nipple equal to twice the thickness of the shell plate, or $1\frac{5}{16}$ inches.

(d) The shell plates and butt straps are bent cold, to the proper curvature of the drum shell, in a large hydraulic press, which forms the long plates quickly and accurately. The shell plates and straps are pickled after being bent.

Riveting.—The longitudinal seams, with their double butt straps, are held by six rows of rivets. Four of these six rows pass through both the two butt straps and the shell plate. The inside butt strap is $4\frac{1}{2}$ inches wider than the outside strap, and the two other outer rows of rivets pass through only this inside strap and the shell plates. The riveting through both straps is double zigzag, with each alternate rivet omitted in the inner row and in the outer row.

All riveting is done by hydraulic riveters, each rivet being driven with a pressure of at least 60 tons and held until cool. The rivet holes are first punched with a $\frac{9}{16}$-inch punch, which is $\frac{5}{16}$ inch less than the diameter of the rivets used; then, after the plates have been bent and bolted together in place, the holes are drilled to $\frac{23}{32}$ inch.

Drum Heads.—The drum heads are $\frac{3}{4}$ inch in thickness and are pressed from flat, circular plates 52 inches in diameter. The several operations of flanging a drum-head plate, dishing or "bumping" it spherically, punching out the manhole in the center, and pressing the inside reinforcing ring around the manhole are done in one hydraulic press and at a single heat, an admirable process that gives a strong, neat and smooth head. The radius of the spherical bump is 42 inches, equal to the inside diameter of the drum. The heads are rivited to the shell with double zigzag riveting. The drum heads are not pickled because some of the pickling acid might get under the reinforcing ring which is pressed around the manholes and start corrosion.

Openings in the Drum.—There are three steam openings in the drum: one from which the main and auxiliary pipes lead, one for the safety valves, and one for a fitting to which are attached the steam gauge, sentinel valves and air cock. There are three water openings: one for main feed, one for auxiliary feed and one for the surface blow. There are also two small openings for each one of the two water gauges, and three small openings for

the test cocks. Around each of these openings (except for the test cocks) is riveted a forged-steel nozzle or pad, as shown in Figs. 7, 8. The face of each nozzle is machined and recessed for the joint of the valve or fitting which is connected to it. This nozzle forms a strong and convenient means of attachment for these valves and fittings. The nozzles are pressed from ¾-inch steel plate and conform closely to the curvature of the drum. The joints between the nozzles and the valves or fittings are made with corrugated copper gaskets.

Fittings.—Each drum has two water gauges and three test cocks. The fittings of the water gauges are of the Dewrance type; in case the gauge glass should burst, the water end is automatically closed by a ball in the bottom of the fitting, the top being closed by a cock operated by a chain from the fireroom floor. In the latest design, the guage glass is protected by a guard of heavy plate glass, which is much better than the old mica gauge formerly fitted. A reflex water gauge, of the Klinger pattern, is being adopted for the latest boilers, one being fitted to each boiler. The glass, which is flat, has V-shaped corrugations on its inner surface, cut at a carefully determined angle and pitch to produce refraction and reflection of light. This makes the water back of the glass look black and gives the steam space above it a silvery appearance. Due to this contrast the water line can be seen very distinctly.

Interior Fittings.—In the lower half of the drum are fitted semi-circular swash plates to retard the movement of the water when the ship is rolling. These swash plates are held by pieces of ½-inch flat steel, 2½ inches in width, riveted to the drum. The zincs, all of which are in the drum, in six groups of five each, are carried in perforated baskets of rectangular shape, the zincs being strung on bolts which pass from side to side of the basket. The supports for the zinc baskets are riveted between and to the swash plates, the basket being placed between two of the swash plates. The zincs are perfectly accessible and are easily renewed. The curved baffle plates over the ends of the circulating tubes are secured by hinges of flat steel to lugs riveted to the shell; they are held down in place by latches, and are divided between

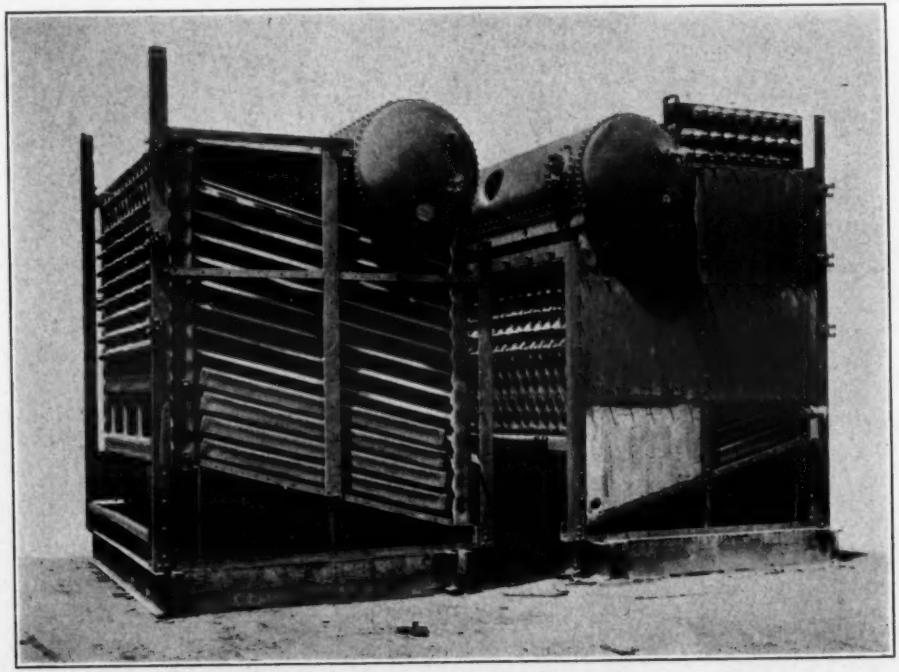


Fig. 5.—Babcock & Wilcox Boilers, U. S. S. "Chicago"; Showing Upright Type, Vertical Headers.

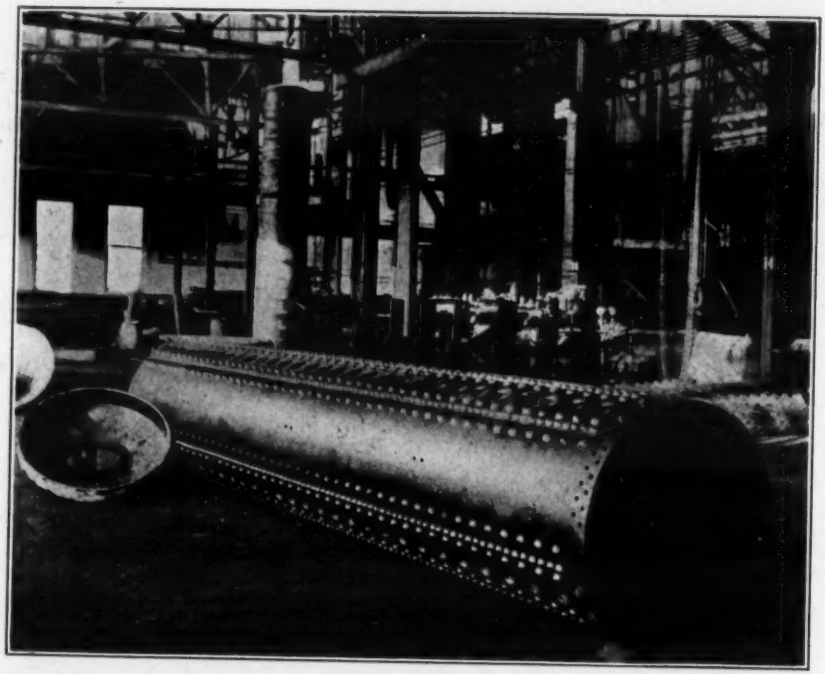


Fig. 6.—Steam and Water Drum; Babcock & Wilcox Boiler, Details of Construction.

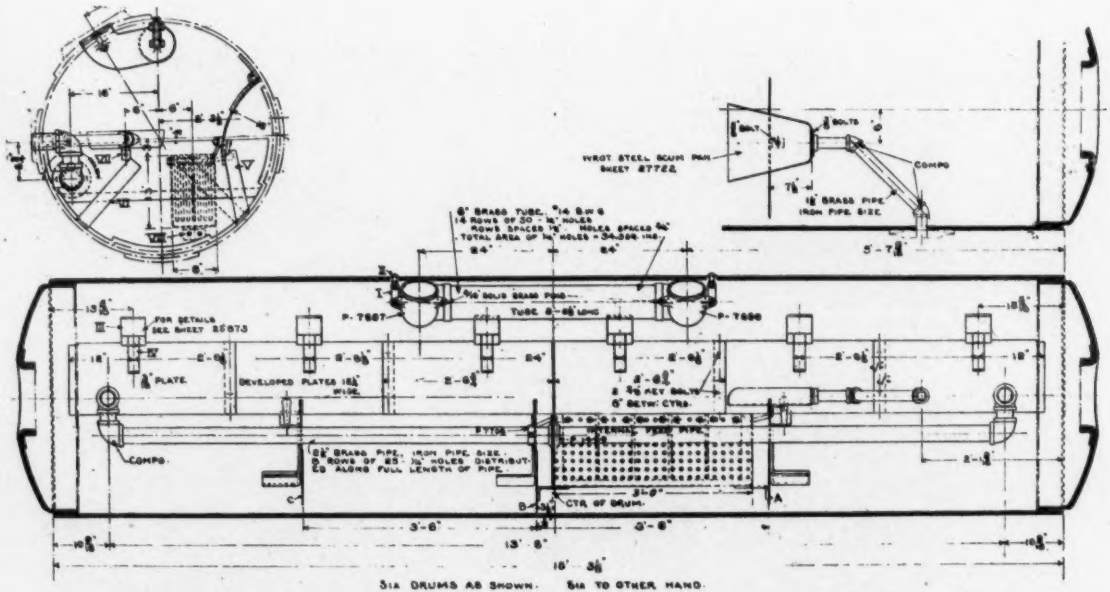

WROT STEEL SCUM PAN SHEET 87722
COMPO
18" BRASS PIPE IRON PIPE SIZE
5'-7⅞"
6" BRASS TUBE, No 14 B.W.G
14 ROWS OF 50 - ⅜" HOLES
ROWS SPACED 1⅝" HOLES SPACED 4½"
TOTAL AREA OF ⅜" HOLES = 34.364 INS.
24"
24"
P-7687
P-7686
TUBE 6'-0½" LONG
FOR DETAILS SEE SHEET 85873
DEVELOPED PLATES 18½" WIDE
2'-6½"
2'-6½"
2'-6½"

Fig. 10.—Making Up "Sections"; Expanding Tubes in Headers.

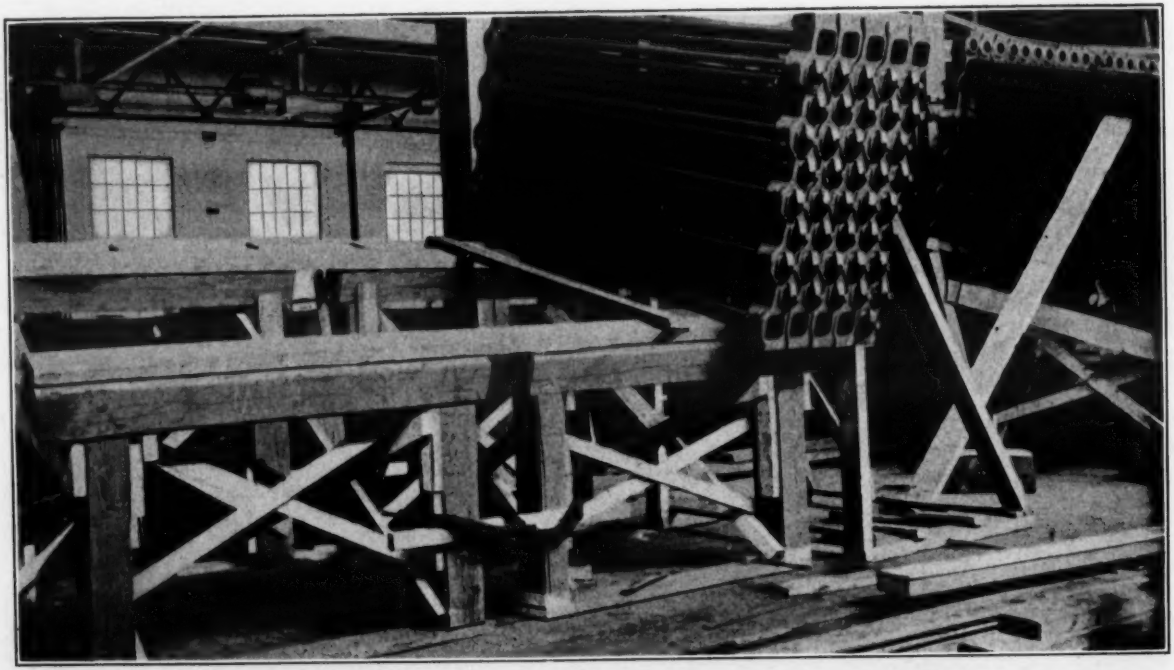


Fig. 11.—Assembling the Sections of a Babcock & Wilcox Boiler; First Stages.

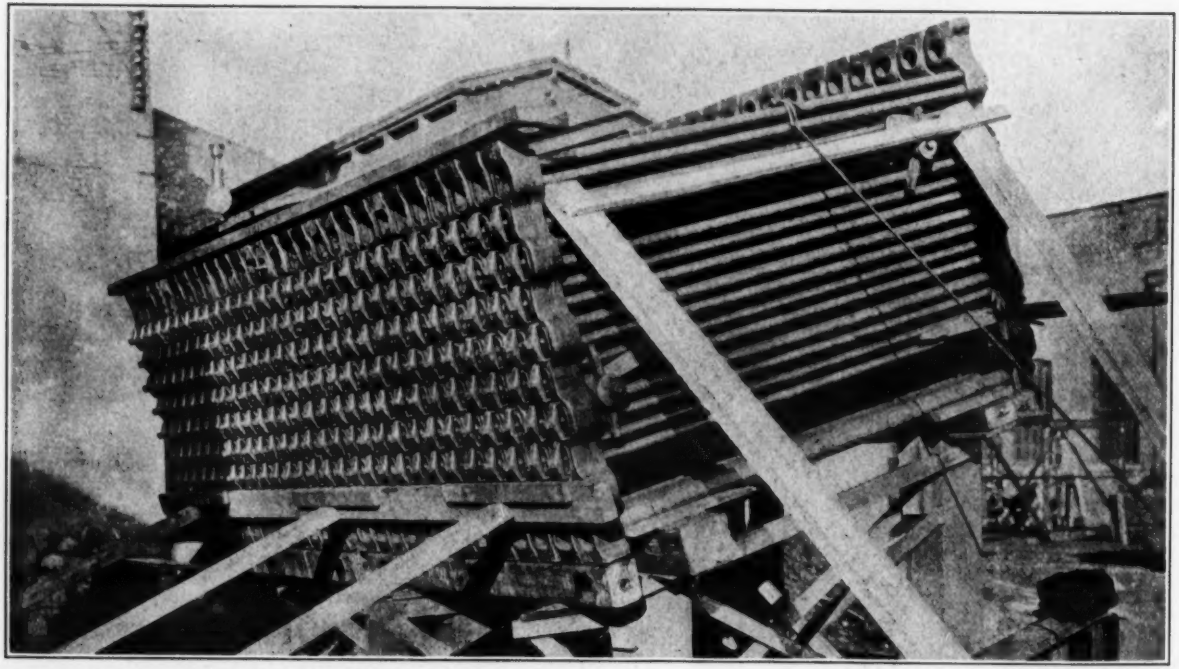


Fig. 12.—Assembling the Sections of a Babcock & Wilcox Boiler.

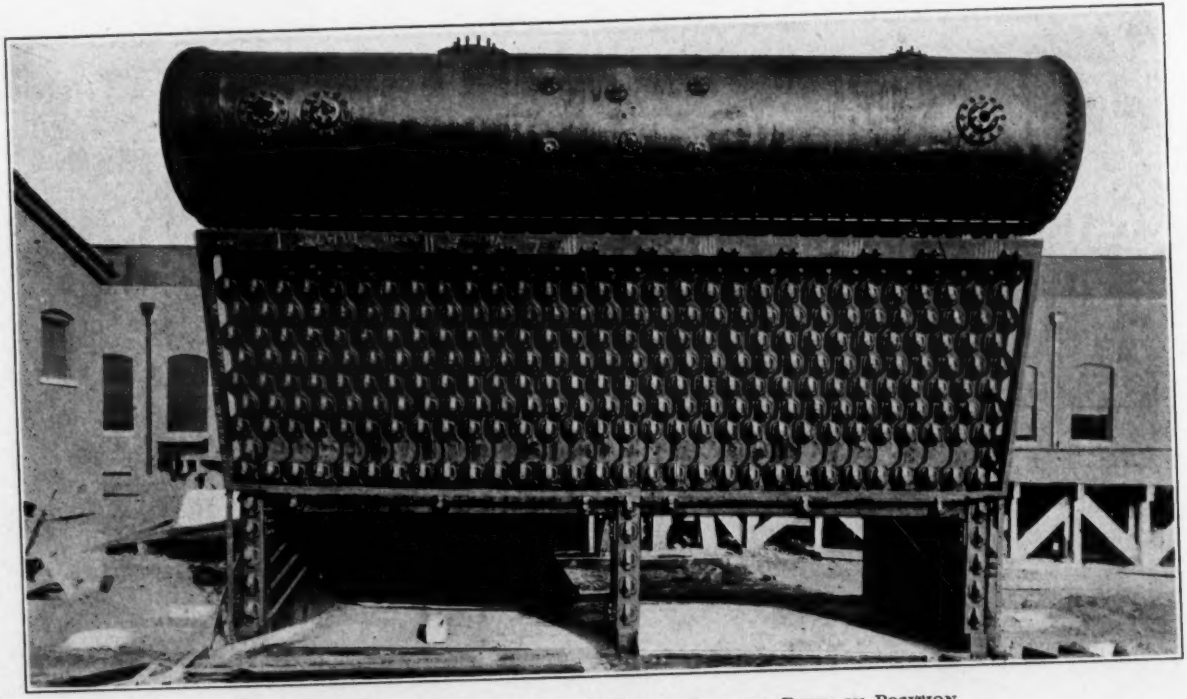


Fig. 13.—Assembling a Babcock & Wilcox Boiler; Drum in Position.

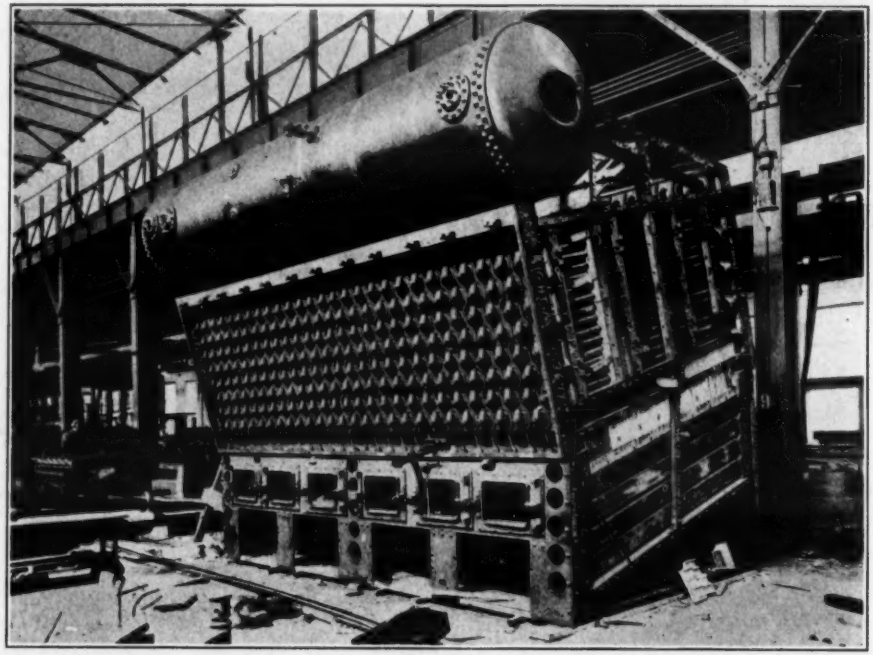


Fig. 14.—Assembling a Babcock & Wilcox Boiler; Ready for Fire-Tiles and Casings.

the swash plates. There are two internal feed pipes, one main and one auxiliary, of 2½-inch brass pipe and extending for 3½ feet parallel with the axis of the drum; in the upper half of each are eight rows of ¼-inch holes, twenty-five holes in each row, space between rows 1½ inches.

A dry pipe of 5-inch brass tube connects the two steam openings in the drum shell; the upper half of this pipe has eleven rows of ¼-inch holes, 57 in a row, holes spaced ½ inch, the combined area through holes being 31 square inches.

The scum pan is a flat pan of rectangular shape, formed from steel plate by a hydraulic press.

The interior of the drum is not obstructed in any way, and a man may pass with ease from one end to the other. The arrangement is shown in Fig. 8.

There are no zincs in any other part of the boiler. It seems that it would be advisable to fit a few zincs in the front cross-box and in the corner boxes in order to protect these parts. The lower part of the boiler is without any protection of this kind.

HEADERS.

The header is, perhaps, the most important pressure part of the boiler and is made of open-hearth steel plate, ½ inch in thickness and of a tensile strength of from 52,000 to 58,000 pounds per square inch.

After the several operations from rough material to the characteristic shape of the header as shown in the several illustrations, that is, a staggered tube of rectangular cross section with rounded corners, the header is next tested to an internal, hydrostatic pressure of 600 pounds to the inch, for leaks, defects in the welds, etc. After having been tested, it is taken to the machine shop for finishing.

The header is now laid off for machining, the centers of the hand holes and of the 2-inch tube holes being marked; if it be a front header, the centers are laid off for the holes through the end plugs for the nipples connecting the drum at the top and the cross box at the bottom. In laying off, the center line used is the

center of figure of the header as a whole; this insures a better fitting together of the headers when they are erected in the boiler.

Pilot holes for cutting the hand holes are now drilled in the header; then, with these pilot holes as centers to guide the cutters, 4½-inch holes are cut, as a first step towards cutting the hand holes. Then these 4½-inch circular holes are *broached*, that is, their edges are sheared roughly to the rectangular form of the hand hole. Then these *broached* holes are finished, in a multiple machine of special design that cuts all the holes simultaneously, to nearly the final contour and dimensions. The holes are finally filed accurately to a gauge.

The 2-inch tube holes are now drilled in a multiple machine that drills from nine to eleven holes simultaneously.

11. The hand holes are now faced on the inner surface of the header in a milling machine of special design, the edge of the hole serving as a guide for the milling cutter; only one hole can be faced at a time. The cutter mills a face around the periphery of the hole on the under or inner surface of one side of the header. It is against this face that the joint of the hand-hole plate is made.

12. In the ends of those headers that are to be used in a side section (or in the middle section of a boiler which is more than twenty-three sections in width), and which step into the tops of the corner boxes, a heavy plate 1½ inches in thickness, is welded.

After the 4-inch nipple holes have been drilled in the ends of these headers they are given a second test to a pressure of 600 pounds, to ensure that the welds in the ends have not been hurt by the drilling; this second test is also made for front headers after drilling the holes in the ends.

The corrugated form of the header gives to it great strength and stiffness. In an attempt to burst a header, a pressure of 3,500 pounds per square inch has been applied without any evidence of damage or strain.

After the hand holes are finished, there is left between any two adjacent hand holes a strip of metal or bridge only 1¼ inches in width. When the header is subjected to internal pressure there is, of course, a tendency for the corrugated side walls to spread

open, this tendency being resisted by the bridges of metal between the hand holes. These bridges might seem to be a weak point of the header. That they are not has been recently demonstrated by a striking experiment. All the bridges were cut, a large plate was fitted in to make the header tight, and hydrostatic pressure was applied inside the header. There was no sign of deformation, and the plate did not begin to leak from the spreading out of the side walls until a pressure of 500 pounds had been reached. This header is shown in Fig. 9.

In the process of forming, should any cinder or dirt cling to the bottom of the mandrel that is forced into the header and be carried along with the mandrel into the header, this cinder or dirt would be pressed down into the surface of the header (inside) and give the metal a pitted appearance. Headers having this appearance on the inside are very carefully calipered, and are thrown out if below the normal thickness; so no alarm need be felt by those aboard ship if a few of the headers of a new boiler have the appearance of being pitted.

FOUNDATIONS, SUPPORTS, ETC.

The foundations are of the shape of a right-angled triangle, each built up of two 8-inch channel irons, about $\frac{1}{4}$ inch in thickness, to the inside flanges of which is riveted a piece of $\frac{1}{4}$-inch steel and two *chair pieces* of flat steel, 5 inches $\times$ $\frac{3}{4}$ inch, bent to the shape in the sketch. One channel laid horizontally, flanges up, forms the base; the other, laid at an angle of 15 degrees with the horizontal, flanges down, forms the top of the foundation. Each *chair piece* is connected to the base by two $\frac{3}{4}$-inch countersunk rivets, one through each foot; to the side plate by two 2-inch $\times$ 2-inch $\times$ $\frac{1}{4}$-inch angle irons; to the top channel by a flat steel angle piece, $4\frac{1}{2}$ inches $\times$ $2\frac{1}{4}$ inches. The top channel is supported at the middle of its length by a 3-inch $\times$ 3-inch $\times$ $\frac{1}{4}$-inch angle. In each foot of each saddle piece there is a $1\frac{3}{4}$-inch hole, through which the holding-down bolts pass. In the top of each saddle piece there is a hole $2\frac{1}{8}$ inches diameter, through which the lug in the bottom of the corner box passes; this lug holds the boiler to the foundation. There are three of these foundation

pieces in the wide boilers for the larger ships, *i. e.*, in boilers over twenty-three sections wide.

On the chair pieces of the foundations rest the four corner boxes and the middle boxes, held in place by the 2-inch stud and nut in the bottom of the corner and middle boxes.

To support the back ends of the sections an I beam, 7 inches between flanges, is secured at each end, to and between these vertical boxes, by bracket pieces of steel, 6 inches × 3 inches × $\frac{5}{8}$ inch, with tap bolts. These I beams form also a support and place of attachment for the back plate of the bridge wall and the frame of the rear-tube door. The back plate of the bridge wall is also held at the sides by angle irons to the middle and corner boxes.

The front ends of the sections are unsupported, except by the nipples that connect them with the steam and water drum above. The side sections and middle section are stepped into the corner boxes and the middle boxes. The steam and water drum is supported at each end and at its middle point by sleeves, or pieces of 4½-inch pipe, $\frac{5}{16}$ inch in thickness, and 5¼ inches in height. These are fitted around the two end nipples (4-inch nipples) and the middle nipples in the bottom of the drum, and rest on the end headers and the middle header. The expanded joints in the bottom of the drum and the top of the front headers are very strong, and the drum thus serves as a beam to increase the transverse stiffness of the boiler and to support the front ends of the sections. The whole structure is said to be surprisingly stiff.

The boiler is held down by sixteen 1¼-inch bolts, four to each foundation piece, which pass through the holes in the feet of the saddle pieces. The center of gravity of the empty boiler lies, approximately, at the point of intersection of two diagonal lines, one drawn on the side elevation of the boiler, from the center of the drum to the lowest point of the foundation at the back, and the other from the highest point of the rear header to the front point of the base of foundation. The C. G. is thus about six feet above the base. With the boiler filled, this would be raised slightly.

CASING.

The entire boiler, except the drum, is enclosed by an airtight casing, consisting of light fire tiles, ¼-inch asbestos mill board and 2-inch block magnesia, backed with galvanized steel plate, ⅛ inch thick. The fire tiles are shaped so as to fit snugly into the spaces between tubes, as may be seen in Fig. 4. Over these is placed the ¼-inch asbestos mill board, then the magnesia. The plating, No. 10 B. W. G., covering this, is held in place by edge straps, bolted to the casing frame, and easily removed. The water sides of the furnace extend nearly one-half the way up the height of the boiler. The hand can be kept against the casing when under strong forced draft, abreast the water side. All cracks between headers, side boxes, etc., are closed by caulking with rope asbestos.

CORNER BOXES, MIDDLE BOXES AND CROSS BOXES.

The four corner boxes and the two middle boxes (which latter are fitted only in the boilers that are greater in width than twenty-three sections) are folded and welded in the same manner as the headers. They are made of ⅝-inch steel and are 7 inches square, outside. In the top end a 1¼-inch plate is welded; and the bottom end is closed by a 1-inch plate, from the center of which a 2-inch stud projects. This stud fits into the hole in the foundation, and a nut is screwed on the end, to hold the boiler on the foundation. The front face of the rear box and the rear face of the front box are bumped, as shown, to receive the nipples of the four square side boxes and the 4-inch side tube, which form the water side of the furnace.

The front cross box, or mud drum, is likewise of ⅝-inch steel, having ¾-inch plugs welded in the ends; and 4-inch holes are cut in the upper side to receive the nipples of the front headers. The cross boxes are supported by brackets, tap-bolted to the front corner boxes and middle box. Access to the interior of the cross boxes is provided by handholes cut in the front side. The corner boxes and middle boxes form the supports of the boiler. The plane of the tops of these boxes is at an angle of fifteen degrees with the horizontal, as shown.

Handholes are cut in the corner boxes, opposite the ends of each side box and 4-inch tube.

It seems that the fitting of a middle *upright*, or vertical box, in the middle of a boiler, fifteen or more sections wide, to give better support to the front cross box and front ends of the sections, as well as to provide better means of securing the boilers in the ship, by giving an additional foundation, and make a narrower grate, would improve the design.

SECTIONS.

The sections are built on inclined "*ways*," the distance between the ways being equal, roughly, to the length of the tubes in the section. The headers are laid on the ways, with their tube faces inside, and the tubes are expanded in their holes in the headers by power expanders; these expanders travel up and down other *ways* which are parallel with and at a distance of about four feet from the ways on which the headers rest. There is one of these power expanders for each end of the section under construction, and the expanding of the two ends of any one tube is done simultaneously, as shown in Fig. 10.

When completed, each section is tested to an internal hydrostatic pressure of 500 pounds per square inch, and any leaking tube ends are re-expanded.

After inspection at the mills the tubes are coated with boiled linseed oil for protection against rust. This oil is carefully cleaned from the ends of the tubes for a distance of about two inches before the tube is expanded in the header. This cleaning is done in a lathe and with files and emery paper. Great care must be taken to remove all traces of oil from that portion of the tube that is expanded in the hole in the header, as a slight film of oil will cause irremediable leaking.

ERECTING BOILERS.

Before shipping from the works, the boilers are assembled and erected in the shop, each component part being carefully fitted in its place and then numbered in such a manner as to define its exact position relative to the other parts. The sections are

numbered consecutively from left to right, as one faces the boiler front. Figs. 11, 12, 13 and 14 show the stages of this work.

First, wooden horses, the tops of which lie in a plane at an angle of 15 degrees with the horizontal, are erected on the floor of the shop; and, on top of these are placed the sections in a vertical position, each section resting on its lower 4-inch tube. The first section put on the horses (the right one) is made fast by a rope to a wooden upright nailed to the horse; and each successive section is held in place against the preceding one by this rope. When all the sections (except the outermost one on each side of the boiler, which is put up last) are in place on the horses, they are bound together by iron rods, on the ends of which are cross-pieces set up with nuts.

The front cross box or mud drum to which are connected the bottom ends of the sections and the corner boxes, is next put in place under the front headers of the sections, being supported on wooden brackets nailed to the horses. Each section is moved laterally as may be necessary, until a nipple passed through the 4-inch hole in the bottom of each front header strikes fairly the hole in the top side of the cross box. This insures the correct placing of the lower ends of the front headers. The top ends of the front headers are adjusted to a template made of a channel iron in which are a line of 4-inch holes whose centers are the same distance apart as the 4-inch holes in the steam drum.

The intermediate sections being correctly placed, the side sections with the vertical corner boxes and foundations are put in place. The front ends of the foundations are brought into line with the edge of the channel-bar template, and consequently on a line parallel with the centers of the top holes of the front-headers. The drum is then lowered into place, resting on sleeves around the end nipples. The two end 4-inch circulating tubes are expanded in place to hold the drum.

The ash pans, side casing, furnace fronts, back plates, grate bars and bearers are now fitted. Each part is numbered when the boiler is taken down for shipping, and the parts of one boiler are painted a distinctive color to avoid confusion when erecting on board ship.

NOTES.

A NEW FORM FOR STEAM- AND HAND-OPERATED STOP AND THROTTLE VALVE.

By COMMANDER A. B. WILLITS, U. S. N.

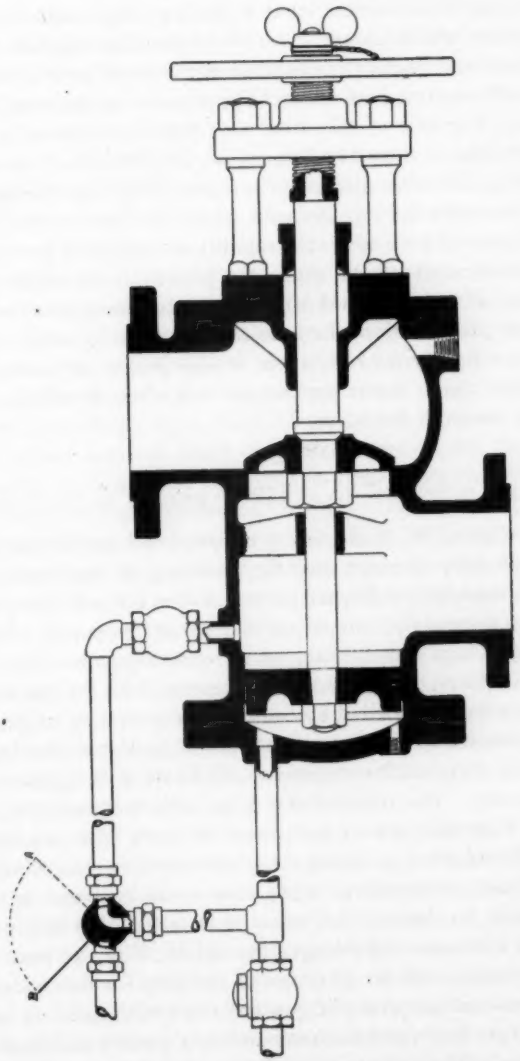
The accompanying sketch has little need of verbal explanation; its simplicity is obvious and its mode of operation readily comprehended.

The specifications for the machinery of many of our ships call for steam-closing boiler stop valves, and, heretofore, these valves have been designed with a steam cylinder separate from the valve chamber and in which steam was used for closing the valve only. Two stuffing boxes were necessary, and the keeping of these tight was an added difficulty.

With the arrangement here shown, the invention of the writer, the valve and actuating piston are in the same chamber and the operating two-way cock can be located wherever desired.

Mode of Operation.—As a hand-operated valve, its functions are obvious and need no extended description.

As a steam opening and closing stop or throttle valve, the hand nut on the end of the valve stem is unscrewed entirely from the threaded end (as it always is when the valve is in service), but is left attached by a chain, to prevent its becoming lost or mislaid; the screw sleeve is backed from the valve stem shoulder, by means of the hand wheel, sufficiently to permit the valve disc to raise to its "full open" position. Then, to open the valve, the lever of the two-way cock is slowly moved, so as to admit steam from the valve chamber into the chamber at outer end of piston and balance the unit pressure on both sides of the piston. The greater difference in the total pressure on the piston being on the outside (owing to the area of the stem), this difference, together with the pressure on the under side of the valve disc, unseats the latter and opens the valve.



COMBINED STEAM- AND HAND-OPERATING STOP AND THROTTLE VALVE.

To close the valve the lever of the two-way cock is moved to a position which closes the communication between the two chambers and opens the chamber at the outer end of the piston to the atmosphere and releases the pressure on the outside of the piston. The area of this piston on the valve side being greater than the area of the valve disc causes the piston to move outward and bring the valve disc to its seat and thus close the valve. It is obvious that the rapidity with which the lever of the two-way cock is moved determines the rapidity of motion of the valve disc. The connections of the pipes are preferably so made that the chamber at the outer end of the piston becomes filled solid with water of condensation, the inflow and outflow of which will control more rigidly the movement of the piston and also hold the valve disc from chattering on its seat when but little steam is flowing through the valve.

THE ECONOMY OF STEAM TURBINES IN CRUISERS.

The trials of H. M. S. *Amethyst*, completed on November 16th, unmistakeably demonstrated the economy of the Parsons steam turbine, especially at higher powers, as the opportunity presented itself of accurately comparing the results obtained with those arrived at, under exactly the same conditions, in three cruisers of similar form, draught and displacement, with the one difference that they were propelled by ordinary reciprocating engines. The vessels known as the *Topaze* class are of 3,000 tons displacement, and were designed for a speed of 21¾ knots, with 9,000 indicated horsepower. The trials of the ships with reciprocating engines proved that the utmost that could be done with any degree of reliability was 22.34 knots; the *Amethyst*, for the same boiler power, easily steamed at 23.63 knots—an increase in speed of 1.29 miles per hour. But when it is noted that this gain was realized with easier steaming of the boilers, with the same weight of machinery, with no vibration of the ship—which enormously assists towards accuracy of gun fire—and with quite 10 per cent. less coal per hour, and a correspondingly greater radius of action, the superiority of the turbine will at once be appreciated. The

absence of reciprocating parts reduces possibilities of wear and tear. The height required for the turbine machinery is 20 inches less, so that it can be more easily housed under a protective deck. The air pressure in the stokehold was ½ inch less, so that there was, as a result, less stress on the boilers. The maneuvering capabilities of the turbine cruiser proved quite as satisfactory as the reciprocating-engine ships. The time required for stopping from full speed ahead, or from starting from dead stop, ranged from 7½ to 20 seconds, and only a few minutes was required to increase the ship's speed from 10 knots to 22 knots, so that the tactical advantage of the turbine need not be doubted. Economy is the one great element proved by the exhaustive and very carefully-conducted trials of all four ships. At low power for 10 knots speed the water consumption was about 23 per cent. higher than in the reciprocating-engine ship. This excess, however, will be very materially reduced when the exhaust steam from the auxiliary engines on board the *Amethyst* is passed into the low-pressure turbine receiver instead of into the condenser—a practice carried out in the other ships. At 14 knots the conditions are, so far as economy is concerned, more equal; but when the speed was increased to 18 knots it was found that the consumption on board the *Amethyst* was something like 20 per cent. less; at 20 knots it was nearly 30 per cent. less, and at the higher speed the improvement was still greater. The influence of this economy on the radius of action is very marked; for instance, the turbine-propelled ship could, with her 750 tons of coal on board, steam 3,160 sea miles at 20 knots, as compared with 2,140 miles by the cruisers fitted with the ordinary machinery.

Turning now to the details which we have collated from the trials of these respective vessels, we may note first that the *Amethyst*—the vessel supplied with steam turbines by the Parsons Marine Steam Turbine Company, of Wallsend-on-Tyne—was constructed by Sir W. G. Armstrong, Whitworth and Co., at the Elswick Works. The other three ships are the *Sapphire*—constructed and engined by the Palmers Shipbuilding and Iron Company—and the *Topaze* and *Diamond*—constructed and engined by Laird, Cammell and Co., at their Birkenhead Works. So far

TABLE I.—RESULTS OF STEAM TRIALS OF H. M. S. "AMETHYST" WITH PARSONS STEAM TURBINES.

Date of trial	Oct. 19 and 20.	Oct. 24 and 25.	Oct. 31 and Nov. 1.	Nov. 4.	Nov. 8.	Nov. 16.
Duration of trial, hours	24	24	30	8	4	4
Draught of water (mean), feet and inches	14-7	14-7	14-6	14-8	14-7	14-6
Speed of ship, knots	10	14.062	18.186	20.6	23.06	23.63
Air pressure in stokeholds, inch	1.9	0.3	0.45	0.46	1.7	1.6
Steam pressure in boilers, pounds	259	263	246	255.2	243.7	260.6
Steam pressure in receivers:						
Cruising H.P., pounds	94	216	...	...	...	...
I.P., pounds	19	61.2	137.5	190.6	...	...
Main H.P., pounds	2.7	18	53.7	75.6	158.3	174.3
starboard L.P.	Vac. 21.7 in.	Vac. 10.8 in.	1.3 lbs.	6.1 lbs.	23.5 lbs.	27.3 lbs.
port L.P.	Vac. 19.9 in.	Vac. 11.8 in.	Vac. 1.3 in.	4.8 lbs.	24.6 lbs.	27.3 lbs.
Vacuum in condensers:						
Starboard, inches	26	27	26.6	27.8	26.9	26.5
Port, inches	26.7	26	27.6	27.8	27	27.4
Revolutions:						
Center	167.2	237.4	319.8	361.1	436	449.4
Starboard	198.2	289.7	391.6	450.8	488.8	484
Port	204.2	290.5	348.1	402.1	492.9	499
Consumption of water per hour, pounds	26,260	44,090	76,493	100,606	176,845	190,525
coal, per hour, pounds	2,893	4,725	8,372	10,937	24,035	24,412

TABLE II.—RESULTS OF STEAM TRIALS OF H. M. S. "TOPAZE" WITH RECIPROCATING ENGINES.

Date of trial	August 1 and 2, 1904.		August 2 and 3, 1904.		July 12 and 13, 1904.		August 7 and 8, 1904.		August 10, 1904.		July 28, 1904.		August 13, 1904.	
Nature of trial	24 hours at 10 knots.		24 hours at 14 knots.		30 hours at 18 knots.		30 hours at 18 knots.		8 hours at 20 knots.		4 hours at full power.		4 hours at 21¾ knots.	
Speed of vessel, knots	10.058		14.08		18.1		18.069		20.063		22.103		21.826	
Steam pressure in boilers, pounds per square inch	200		198		240		250		250		271		276	
Number of boilers in use	4		6		8		8		10		10		10	
Air pressure in boiler rooms, ins.	0.2		0.28		1.19		0.87		0.83		1.8		2.04	
Vacuum :														
Starboard, inches	25.7		26		24.8		25.7		25.2		24		25.3	
Port, inches	25.3		25		24		24.8		24.4		24		23.8	
Revolutions :														
Starboard, inches	107.5		150.7		198.6		195.7		219.6		245.6		242.8	
Port, inches	106.5		150.3		196.8		195.7		219.2		245.5		243.8	
Mean, inches	107		150.5		197.7		195.7		219.4		245.55		243.3	
Mean pressure in receivers :	Stb'd.	Port.	Stb'd.	Port.	Stb'd.	Port.	Stb'd.	Port.	Stb'd.	Port.	Stb'd.	Port.	Stb'd.	Port.
High, pounds	75	74	142	150	192	190	188	190	216	214	244	245	240	237
Intermediate, pounds	13.6	13.9	39	46	59	60	59	61	74	76	89.6	94.4	89	96.5
Low, pounds	3.6 in. vac.	5.2 in. vac.	2.8	4.2	12	13.8	8.7	10.6	14	15	22.2	23.1	22.5	23.9
Mean pressure in cylinders :														
High, pounds	20.82	20.88	38.57	34.63	74	62	64.6	61.8	80	80	115	111	102.6	94.5
Intermediate, pounds	6.94	7	15.57	15.15	26.1	28.4	26.7	27.3	34.2	36.6	44.5	47.2	44	49.9
Low forward, pounds	6.34	6.07	9.25	10.36	13.8	15.2	13.29	15.04	16.7	17.26	20.1	21.5	20.7	22.84
aft, pounds	5.69	5.82	8.99	9.75	13.8	15.5	13.55	15.37	16.61	17.35	21.5	22.7	21.46	23.6
Mean, I.H.P. :														
High	125	125	326	292	821	684	706	678	983	982	1,585	1,534	1,395	1,292
Intermediate	106	105	331	321	733	790	735	755	1,058	1,132	1,541	1,637	1,508	1,716
Low forward	116	110	237	265	466	511	441	501	623	644	841	897	853	946
Low aft	104	106	230	249	467	521	449	511	620	647	897	946	885	978
Indicated horsepower	897		2,251		4,493		4,776		6,689		9,868		9,573	
Consumption of coal per hr., lbs.	2,296		4,640		10,484		10,900		15,451		26,150		27,700	
Consumption of coal per I.H.P. per hour, pounds	2.56		2.06		2.3		2.28		2.31		2.65		2.89	
Consumption of water per hour, per I.H.P., pounds	23.74		18.77		19		18.95		20.07		20.18		21.93	
Consumption of water per hr., lbs.	21,294		42,260		94,867		90,500		134,248		199,140		209,950	

as the hull is concerned, all four vessels are alike. With a length of 360 feet and a beam of 40 feet, they displace 3,000 tons when the draught is 14 feet 6 inches; in all of the trials this draught was either equalled or slightly exceeded. They are third-class cruisers, and will probably be used for despatch work, although the speed of the *Amethyst* may justify her being regarded as a scout. The armament includes twelve 4-inch guns—one on the poop, a bow chaser on the forecastle and five on each broadside on the upper deck. These guns have hoods of 4-inch armor. In addition there are eight 3-pounders, three Maxim guns and two torpedo-launching tubes on the upper deck.

The boilers are of the "express" water-tube type, and it was specified that the coal burnt per square foot of heating surface should not exceed 1 pound. In the *Amethyst* the Yarrow boiler, as constructed by Hawthorn, Leslie and Co., has been adopted, the fire-grate area being 493½ square feet, and the heating surface 25,968 square feet, a ratio of 1 : 52.5. In these boilers the constructors have again utilized the method of adopting the two outer rows of tubes for heating the feed water. The top of the water drum to which these tubes are connected is isolated by a diaphragm plate from the remainder of the drum, and into this space the feed water is discharged. This is an important subject in turbine driving, because, owing to the fact that a high vacuum is desiderated, it results that the temperature of the feed water is less than in other ships by about 20 degrees Fahrenheit. The effect of the utilization of these two outer tubes is to heat the water without adding materially to weight carried—always an important matter in warship design. The *Amethyst* tubes are 1⅛ inches in diameter. The Laird-Normand boilers fitted to the *Topaze* and *Diamond* have $1\frac{5}{16}$-inch tubes, but in the Reed boilers in the *Sapphire* the tubes are of $1\frac{1}{16}$ inches diameter. In all cases the two rows nearest the fire are greater in internal diameter to the extent of ¼ inch. The boilers are arranged, in all the ships, two in the forward stokehold and four in each of the other two. All of the ten boilers are single-ended and placed back to back. In each ship the stokehold is closed, the fans being driven by enclosed steam engines, arranged for forced

lubrication. The air pressures on the full-power trial in the reciprocating-engined ships ranged from 1.7 inches to 2.6 inches; in the *Amethyst*, on the other hand, the pressure at full power was 1.7 inches on one trial and 1.6 inches on another. The former was run in very rough weather, when the wind was 4 to 6, and the other with a calm sea. In Table I, where the results of all the trials of the *Amethyst* are set out in detail, it will be noted that at low power the high air pressure of 1.9 inches is recorded. This is explained by the fact that only four of the boilers were used; in the other trials the pressure was normal. The summary of boiler performances, in Table III, shows the result of the higher air pressure, and also indicates how easily the *Amethyst* attained her excess in speed.

TABLE III.—BOILER RESULTS AT FULL POWER.

	Amethyst.	*Topaze.*	*Sapphire.*
Type	Modified Yarrow.	Laird-Normand.	Reed.
Heating surface, square feet	25,968	26,000	26,010
Coal burnt per square foot of heating surface	.93	1	.98
Steam generated per square foot of heating surface, pounds	7.35	8.02	8.7

The reciprocating engines on the two Laird cruisers and on the one Palmers ship are distinctly suggestive of the destroyer type, having at back and front forged-steel columns, braced diagonally. The scantlings are heavier and the working parts are more substantial generally, while the number of revolutions is considerably less. The high-pressure cylinders are 24¼ inches in diameter, the intermediate cylinders 38½ inches, and the two low-pressure cylinders 42½ inches in diameter, the stroke being 24 inches. It was anticipated that the full power of 9,800 indicated horsepower would be developed when the machinery was making 250 revolutions, equal to a piston speed of 1,000 feet per minute. In the case of the *Topaze* the air pumps are worked off the main engines. This was the first of the vessels laid down, and subsequent to the order being placed it was decided that in

the others separate air pumps should be utilized, consistent with later-day practice, adopted in view of the better vacuum obtainable by this method. The auxiliary machinery includes two electric-lighting forced-lubrication engines, the dynamos being of 350 ampères capacity at 150 volts, when the engines are making 450 revolutions per minute; two evaporators, capable of evaporating 60 tons per day; and two distilling condensers, capable of condensing steam from the evaporators at the rate of 20 tons per day, in addition to the usual donkey and other pumps. There is, of course, the usual air-compressing machinery adopted in warships; while in each boiler room there is one main and two auxiliary feed pumps. The enumeration of this auxiliary machinery is justified, because of the question of economy of low speeds, which will be referred to later. The *Topaze*, in addition to making her usual contract trials, was required to carry out trials corresponding exactly with those prescribed for the *Amethyst*. The contract trials were thirty hours at the power which would give 18 knots, eight hours at the power which would give 20 knots, and four hours at full power. In no case were the contractors responsible for the legend speed, which was 21¾ knots, but in all cases it was exceeded.

Before entering upon a consideration of the comparative results, it will be well to indicate generally the arrangement of the turbine machinery on board the *Amethyst*. The difficulty hitherto urged against the turbine for cruisers is the low economy at the cruising speed at which all warships run for 95 per cent. of their time. The Parsons Company have overcome this objection to a greater or less extent in the *Amethyst* by fitting separate turbines for cruising. Thus, at the forward end of the port and starboard shaft respectively there is fitted a high and intermediate-pressure cruising turbine. On the same shaft there are the usual low-pressure turbines for going ahead and the astern turbines; while on the center shaft there is a main high-pressure turbine. The cruising high-pressure turbine has a 44-inch drum; the intermediate cruising turbine, one of the same diameter, but with different blading; the main high-pressure turbine drum is of 60-inch diameter; and the low-pressure tur-

bine of the same diameter, but longer and with different blades. All increase in diameter to admit of the expansion of steam. In cruising it is possible to obtain a great range of expansion, the steam first entering the high-pressure cruising turbine, and passing to the intermediate cruising turbine, thence to the main high-pressure turbine, and through the low-pressure turbines, working *in vacuo*, to the condenser. It will be noticed from the detailed results of the steam turbines on the *Amethyst* on Table I, that this was the arrangement adopted until the speed attained 14 knots; on the trial at 18 knots the cruising high-pressure turbine was cut out, steam initially entering the intermediate cruising turbine, while in one low-pressure turbine there was a pressure of 1.3 pounds, in the other a vacuum. This condition continued at the 20-knot trial, the pressure in all cases, of course, being increased in view of the greater steam supply. At full speed both cruising turbines were cut out, steam entering only the main system. In this way a high rate of expansion of steam at all speeds was attained. The effect on the revolutions of the respective shafts, shown on Table I, is noteworthy, especially on the 18- and 20-knot trials.

It will be understood, of course, that there are separate steam leads to the high-pressure and intermediate-pressure cruising, as well as to the main high-pressure, turbines. Another feature that may be noted is, that forced lubrication has been adopted in connection with the turbine bearings, two small direct-acting oil pumps by Weir having been fitted for this purpose. Separate air pumps by Weir are used for exhausting from the turbines. The Parsons system of vacuum intensifier—which we described in connection with the *Manxman* had not been introduced when the machinery of the *Amethyst* was designed, and, unfortunately, the condenser is too low in the ship to admit of this important addition being made now. A dry-air pump, as in the *Londonderry*, would, however, add to the efficiency.

The water-consumption results were arrived at by measuring the feed water in specially-constructed tanks. On the upper deck there were four tanks for the main feed—two on the port and two on the starboard side—each pair communicating to pipes

running to the feed tanks. The pipe between the pair on the port side, as well as that between the two on the starboard side, had a simple turncock, so that as soon as one tank was filled the flow could be diverted into the other, and the hour or half-hour readings of the gauge determined the amount of water used; the results therefore are reliable.

TABLE IV.—ANALYSIS OF WATER-CONSUMPTION RESULTS.

——	*Amethyst.*	*Topaze.*	*Sapphire.*	*Diamond.*
24-Hours' Trial at 10 Knots.				
Indicated horsepower	897	897	...	...
Speed, knots	10	10.058	...	...
Total water per hour, pounds	26,260	21,294	...	...
Water per I.H.P. per hour, pounds	29.3	23.74	...	...
24-Hours' Trial at 14 Knots.				
Indicated horsepower	2,250	2,251	...	...
Speed, knots	14.062	14.08	...	...
Total water per hour, pounds	44,090	42,260	...	...
Water per I.H.P. per hour, pounds	19.6	18.77	...	...
30-Hours' Trial at 18 Knots.				
Indicated horsepower	4,770	4,776	5,012	5,074
Speed, knots	18.186	18.069	18.47	18
Total water per hour, pounds	76,493	90,500	99,200	96,410
Water per I.H.P. per hour, pounds	16	18.95	19.8	19
8-Hours' Trial at 20 Knots.				
Indicated horsepower	7,280	6,689	7,281	7,145
Speed, knots	20.6	20.063	20.68	20
Total water per hour, pounds	100,606	134,248	144,160	137,930
Water per I.H.P. per hour, pounds	13.8	20.07	19.8	19.31
4-Hours' Trial at Full Power.				
Indicated horsepower	13,000 14,000	9,573 9,868	10,200	*
Speed, knots	23.06 23.63	21.826 22.103	22.34	...
Total water per hour, pounds	176,845 190,525	209,950 199,140	226,440	...
Water per I.H.P. per hour, pounds	13.6 13.6	21.93 20.18	22.2	...

* The *Diamond* has not yet run her contract full power.

On Table IV we have set out the water consumption per hour and the rate per unit of power. The power in the case of the *Amethyst* is, of course, assumed; but as the form of the ship is identical in all cases, we cannot be far wrong in taking the same powers for the *Amethyst* as were required to drive the other ships at corresponding speeds. It is not, however, so easy to deduce the power for the speeds attained by the *Amethyst* in excess of

those realized by the *Topaze;* but the projection of a progressive speed curve affords a moderately accurate assumption. As, however, objection might be taken to this assumed power, we have plotted the water consumption per hour for various speeds without regard to the power. For the lower powers, the turbine required more steam, but, as we have already mentioned, the *Amethyst* has not the advantage of the utilization of the exhaust steam from the auxiliary machinery. In the *Topaze*, for instance, when running at 10 knots, the water used for the auxiliary machinery was 4,538 pounds per hour, or over 21 per cent. of the total, and at 14 knots it was 5,672 pounds, or over 13 per cent. of the total given in Table IV. Although most of the auxiliary engines are compound, some are only simple expansion; the steam exhaust from them is thus by no means a negligible quantity in respect of economy. In the reciprocating-engined ship this exhaust steam is led into the low-pressure cylinder receiver, whereas in the turbine ship it was passed into the condenser. The advantage of the reciprocating engine at low powers will greatly diminish, if it does not disappear entirely, when these conditions are alike. The advantage of the turbine vessel in economy after 18 knots is obvious, and at 20 knots is very marked, while at the designed speed of 21¾ knots it is nearly 30 per cent.

The steam consumption of the *Topaze* shows a satisfactory thermal efficiency. Taking the water used for the main engines only, we find that at 18 knots the steam consumption was 15.45 pounds, while at 14 knots it was 16.25 pounds, and at 20 knots 16.91 pounds. The trials conducted by the Research Committee of the Institution of Mechanical Engineers, recorded as the best performance 13.35 pounds per horsepower hour, but this was in a ship where economy was the main consideration rather than speed for the minimum of weight. Accepting the horsepower assumption, the performance of the turbine machinery proves to be more satisfactory than this exceptional result recorded by the Research Committee. At 20 knots the steam consumption of the turbines, even including the auxiliary machinery, was 13.8 pounds, which is a very exceptional figure, but was carefully tested. At 18 knots, where again there can be no question of the power in view of the

comparison with the other ships, the water consumption was 16 pounds, including that for auxiliary machinery, so that it would be a safe assumption to say that the main turbines were not taking more than 13 pounds, which is probably a better result than has been realized by any high-speed reciprocating machinery in normal work.

TABLE V.—ANALYSIS OF COAL-CONSUMPTION RESULTS.

.....	*Amethyst.*	*Topaze.*	*Sapphire.*	*Diamond.*
24-Hours' Trial at 10 Knots.				
Indicated horsepower	897	897	...	...
Total coal burnt, tons	31	24.6	...	...
per hr., lbs.	2,893	2,296	...	...
per I.H.P., lbs.	3.22	2.56	...	...
Evaporation per pound of coal, lbs.	9.1	9.3	...	...
Miles run per ton of coal	7.42	9.75	...	...
24 Hours at 14 Knots.				
Indicated horsepower	2,250	2,251	...	...
Total coal burnt, tons	50.63	49.7	...	...
per hr., lbs.	4,725	4,640	...	...
per I.H.P., lbs.	2.1	2.06	...	...
Evaporation per pound of coal, lbs.	9.35	9.13	...	...
Miles run per ton of coal	6.6	6.8	...	...
30 Hours at 18 Knots.				
Indicated horsepower	4,770	4,776	5,012	5,074
Total coal burnt, tons	112.13	146	157	154.3
per hr., lbs.	8,372	10,900	11,720	11,520
per I.H.P., lbs.	1.75	2.28	2.338	2.27
Evaporation per pound of coal, lbs.	9.15	8.3	8.45	8.35
Miles run per ton of coal	4.8	3.7	3.53	3.5
8 Hours at 20 Knots.				
Indicated horsepower	7,280	6,689	7,281	7,145
Total coal burnt, tons	39.06	55.2	57.65	59.1
per hr., lbs.	10,937	15,451	16,142	16,570
per I.H.P., lbs.	1.5	2.31	2.217	2.32
Evaporation per pound of coal, lbs.	9.7	8.7	8.94	8.34
Miles run per ton of coal	4.22	2.9	2.86	2.7
4 Hours at Full Power.				
Indicated horsepower	13,000 14,000	9,573 9,868	10,200	...
Total coal burnt, tons	42.9 43.6	49.5 46.6	45.87	...
per hr., lbs.	24,035 24,412	27,700 26,130	25,688	...
per I.H.P., lbs.	1.85 1.74	2.89 2.65	2.518	...
Evaporation per pound of coal, lbs.	7.35 7.8	7.56 7.95	8.75	...
Miles run per ton of coal	2.15 2.17	1.76 1.9	1.95	...

In regard to the coal-consumption results set out in Table V, there is not, perhaps, the same measure of reliability. Disturbing variants come in: the weather, the skill of stokers, the calorific value of coal, &c.; but it is important to note that the coal results corroborate the water or steam economy of the turbine.

In the lower power trials of both ships it will be noted that the evaporative results are fairly constant—about 9 pounds to 9½ pounds per pound of coal; but with the pressing of the boilers to a greater extent, there was a slight falling off. In the case of the reciprocating-engined ships, the boilers were at full power burning 50 pounds to 57 pounds per square foot of grate per hour, which even with perfect control of the stokers is not conducive to high evaporation; but even then the evaporation only slightly fell below 8 pounds in the *Topaze* and was 8.75 pounds in the *Sapphire*. The better result realized on the second full-power trial of the *Amethyst* was due to better weather, and in the case of the *Topaze* to less restrictive conditions in the machinery room.

A better measure of the coal economy is perhaps the distance travelled by the ships at any given speed per ton of fuel, and this also is given in Table V. Here, again, the *Topaze* has the advantage of the power recovered from the exhaust from the auxiliary machinery, excepting at full power; but from 14½ knots upwards the *Amethyst* shows superiority. It is most marked at the higher powers; and a good measure of this is the radius of action. From the coal consumption per hour for the various speeds we have deduced the figures given in Table VI. At 18 knots the turbine-driven ship has an advantage equal to 30 per cent. over the *Topaze*, and at 20 knots of 47 per cent.

TABLE VI.—RADIUS OF ACTION (750 TONS COAL CAPACITY).

Speed in Knots.	*Amethyst.*	*Topaze.*
10	5,570	7,300
14	4,950	5,100
18	3,600	2,770
20	3,160	2,140
22	—	1,420
23.63	1,620	—

A word may be said about the speed results. The propulsive efficiency is in all cases very favorable. In the *Topaze*, four-bladed propellers were fitted on each of the two shafts, and in the *Sapphire* three-bladed screws; but the diameter, pitch and area were in both cases exactly the same. Into the results due to these differences we do not propose to enter, but it is satisfactory to know that the propellers on the *Amethyst* gave an average slip. In this case there was one propeller on each shaft, each of the propellers being three-bladed. The diameter in all cases was 6 feet 8 inches, but the pitch of the side screws was 5 feet 9 inches, the area being 19.48 square feet, while the pitch of the center propeller was 6.56 feet, with an area of 19.64 square feet. At 10 knots the mean slip of the three propellers works out to 11.3 per cent.; at both 14 knots and 18 knots, to 13.6 per cent.; at 20 knots, to 14.4 per cent.; at 23.06 knots, under the very heavy weather conditions to which we have referred, 18.4 per cent.; and at 23.63 knots, in a smooth sea, to 17.1 per cent. There is the one other fact that the five runs of the *Amethyst*, on the 16th, over the measured mile on the East Coast, north of the Tyne, showed very little variation. The runs are made on slack tide, and the speeds were equal to 23.38 knots, 23.23 knots, 23.53 knots, 23.44 knots, 23.53 knots, giving a mean of 23.42 knots for 473.4 revolutions; but the speed on the four-hours' trial was 23.63 knots for 477.6 revolutions.

A concluding reference may be made to the subject of the weight of the machinery. There is practically no difference between the turbine and the reciprocating-engined ships, notwithstanding the necessity of having cruising turbines in addition to the usual go-ahead and go-astern turbines. The total for the reciprocating-engined ships ranges from 530 tons to 540 tons, being in the case of the *Topaze* 537 tons; in the *Amethyst* the weights worked out to 535 tons. Assuming, therefore, that the machinery developed 14,000 indicated horsepower when the vessel made 23.63 knots, it is evident that the power developed per unit of weight was 26 indicated horsepower per ton; whereas in the *Topaze* it was only 18.3 indicated horsepower per ton. The result, as we have said, proves what has long since been estab-

lished, so far as stationary turbines on land are concerned, that the steam turbine when running at its full designed speed is capable of an economy better than that of the ordinary reciprocating engine. As merchant ships are, for 99 per cent. of their time, running at their full speed, the gain must be very considerable. In such case, also, it would not be necessary to have cruising turbines, so that there seems no reason why there should not be some saving also in the weight.—"Engineering," London.

NEW HAMPSHIRE, NORTH CAROLINA AND MONTANA.—CHIEF CHARACTERISTICS OF 16,000-TON BATTLESHIP, NO. 25, AND 14,500-TON ARMORED CRUISERS, NOS. 12 AND 13, AUTHORIZED BY ACT OF CONGRESS APPROVED APRIL 27, 1904.

The figures within parentheses refer to *North Carolina* and *Montana*, the others to *New Hampshire*.

The following is an extract from this Act:

"That for the purpose of further increasing the naval establishment of the United States, the President is hereby authorized to have constructed by contract or in navy yards as hereinafter provided—

"One first-class battleship, carrying the heaviest armor and most powerful armament for a vessel of its class upon a trial displacement of not more than sixteen thousand tons; to have the highest practicable speed and great radius of action, and to cost, exclusive of armor and armament, not exceeding four million four hundred thousand dollars.

"Two first-class armored cruisers, of not more than fourteen thousand five hundred tons trial displacement, carrying the heaviest armor and most powerful armament for a vessel of its class; to have the highest practicable speed and great radius of action, and to cost, exclusive of armor and armament, not exceeding four million four hundred thousand dollars each."

Bids for these vessels will be opened at the Navy Department at noon, December 15, 1904.

In considering bids submitted, other things being equal, preference will be given to such as guarantee the shortest time for completion.

The maximum time allowed for completion is limited to forty-two months, and no bids will be considered which propose to

exceed that limit. Failure to complete the vessel within the time specified in the contract will involve penalties as follows, viz: $300 a day for the first month succeeding the expiration of the period fixed by the contract, and $600 a day thereafter until the vessel is completed and delivered as prescribed by the contract.

The trials of the vessel will be subject to conditions prescribed by the Department.

These trials will consist of—

First. A speed trial of four hours' duration over a measured course. If on this trial the average speed shall equal or exceed 18 (22) knots an hour for four consecutive hours, the vessel shall be accepted, as far as the speed is concerned.

Second. A progressive speed trial, consisting of about twelve runs over a measured-mile course at varying speeds.

Third. An endurance trial, under all boilers, of twenty-four consecutive hours' duration in the open sea, at an average of not less than two-thirds full horsepower.

If the speed on the four-hour speed trial falls below 18 (22) knots but not less than $17\frac{1}{2}$ ($21\frac{1}{2}$) knots an hour the vessel will be accepted, so far as speed is concerned, at a reduced price, the reduction being at the rate of $50,000 a quarter knot deficiency of speed from 18 (22) to $17\frac{3}{4}$ ($21\frac{3}{4}$) knots, and at the rate of $100,000 a quarter knot deficiency of speed from $17\frac{3}{4}$ ($21\frac{3}{4}$) to $17\frac{1}{2}$ ($21\frac{1}{2}$).

If the speed on the four-hour speed trial falls below $17\frac{1}{2}$ ($21\frac{1}{2}$) knots an hour, the vessel may be rejected, or accepted at a reduced price.

The final trial of the vessel will not take place until a period of six months has elapsed from the date of preliminary acceptance.

The general dimensions and features of the vessel are as follows:

	Battleships.	*Armored Cruisers.*
Length on load-water line, feet	450	502
Breadth, extreme, at load-water line, feet and inches	76–10	72–10½
Displacement on trial, not more than, tons	16,000	14,500
Mean draught to bottom of keel at trial displacement not to exceed, feet and inches	24–6	25–00
Total coal bunker capacity, about, tons	2,350	2,000
Coal carried on trial, tons	900	900
Feed water carried on trial, tons	66	66

Trial displacement is to be understood as meaning the vessel and her equipment complete, with 900 tons of coal, plus two-thirds cruising supply of ammunition, plus two-thirds supply of total stores and provisions; crew, and 66 tons of feed water for steaming purposes.

The hull is to be steel throughout.

ARMAMENT.

Battleship.

Main battery—
- Four 12-inch breech-loading rifles.
- Eight 8-inch breech-loading rifles.
- Twelve 7-inch breech-loading rifles.
- Four submerged torpedo tubes.

Secondary battery—
- Twenty 3-inch, 14-pounder, rapid-fire guns.
- Twelve 3-pounder semi-automatic guns.
- Four 1-pounder semi-automatic guns.
- Two 3-inch field pieces.
- Two machine guns, caliber .30.
- Two automatic guns, caliber .30.

Armored Cruisers.

Main battery—
- Four 10-inch breech-loading rifles.
- Sixteen 6-inch breech-loading rifles.
- Twenty-two 3-inch rapid-fire guns.
- Four submerged torpedo tubes.

Secondary battery—
- Twelve 3-pounder semi-automatic rapid-fire guns.
- Four 1-pounder semi-automatic guns.
- Two .30-caliber machine guns.
- Two .30-caliber automatic guns.
- Two 3-inch field guns.

The above battery complete will be furnished by the Government and will be mounted as follows:

The 12-(10)-inch guns in pairs, in two electrically-controlled, balanced, elliptical turrets, on the center line, one forward and one aft, each with an arc of fire of about 270 degrees.

Battleship.

The 8-inch guns in pairs, in four electrically-controlled, balanced, elliptical turrets, two on each beam, at each end of the superstructure.

The 7-inch guns in broadside, on pedestal mounts on the gun deck behind 7-inch armor, each gun being isolated by splinter bulkheads of nickel-steel of from 1 to 2 inches thick; forward and after guns arranged to fire right ahead and right

Armored Cruisers.

Six-inch guns, four in independent casemates on the main deck, the remainder in broadside on the gun deck, all on pedestal mounts, those on the gun deck behind 5 inches of armor, each gun being isolated by splinter bulkheads of nickel-steel of from 1 to 2 inches thick; casemate guns on main deck behind 5 inches of armor in front, and to have 2 inches of nickel-steel for protection in the

astern, respectively; other 7-inch guns to have the usual broadside train.

The guns of the secondary battery in commanding positions, having a large arc of unobstructed fire, and protected wherever practicable.

All the 7-inch guns are so arranged that their muzzles train inside the line of the side armor, thus leaving a clear and unobstructed side when it is desired to go alongside a pier or vessel.

rear. There will be four of the 6-inch guns at ends of battery arranged to fire right ahead or right astern, respectively; other 6-inch guns to have the usual broadside train. All of the 6-inch guns will be so arranged that their muzzles will train inside the line of side armor, thus leaving a clear and unobstructed side when it is desired to go alongside a pier or vessel.

The 3-inch guns will be mounted as follows: Six in sponsons on the gun deck, six in broadside on the gun deck, and ten in broadside on the main deck. Sponson and other protection of the 3-inch battery on main and gun decks to be 2-inch nickel-steel.

Arrangements will be made whereby the 3-inch guns on the main deck can be quickly and conveniently dismounted, housed and secured.

Four torpedo tubes and accessories will be installed, two each in forward and after submerged torpedo rooms, with necessary directing stations.

Battleship.

Armor and Similar Protection.— The hull is protected at the water line by a complete belt of armor, 9 feet 3 inches wide, having a uniform thickness of 9 inches for about 285 feet amidships, gradually decreased to 4 inches at the stem and stern.

The lower casemate armor extends to abreast the 12-inch barbettes and reaches from the top of the water-line belt to the lower edge of the 7-inch gun ports on the gun deck, and is 7 inches in thickness, the athwartship bulkheads at the ends of this casemate being 7 inches thick.

The casemate armor around the 7-inch guns on the gun deck is 7 inches thick and the splinter bulkheads are from 1 to 2 inches thick. The pro-

Armored Cruisers.

Armor and Similar Protection.— The hull will be protected by a water-line belt of armor worked in vertical strakes amidships, where it will be about 18 feet in height, extending from the protective deck to the gun deck port sills, being stepped down at the ends. To be of a uniform thickness of 5 inches throughout the machinery and magazine space and 3 inches forward and abaft of this.

The upper side armor will be disposed in wake of the 6-inch battery, and will extend from the gun deck port sills to the main or upper deck, and will be 5 inches thick throughout. Nickel-steel 2 inches thick will be disposed in wake of the 3-inch battery.

tection of 3-inch guns is nickel-steel 2 inches thick.

The upper and lower casemate athwartship armor, extending from the shell plating to the 12-inch barbettes, is to be 7 inches thick throughout.

The 12-inch barbettes extend from the protective deck to about 4 feet above the main deck, and consist of 11 inches of armor in front and in the rear, 7½ inches above the gun deck, and 6 inches between berth and gun decks. The athwartship and barbette armor will not have any special framing, the connection of the armor to the decks being sufficient.

The 12-inch turrets will have a front plate 12 inches thick, rear plates 8 inches thick, and top plates 2½ inches thick.

The 8-inch barbettes will be 6 inches thick in front and 4 inches thick in rear, with the upper tube 3¾ inches thick and the lower tube 3 inches thick.

The 8-inch turret front plate will be 6½ inches thick, the rear plates 6 inches thick, and the top plates 2 inches thick.

The conning tower will be 9 inches thick, door 6 inches thick, signal tower 6 inches thick. An armor tube 36 inches in diameter will extend from the base of the conning tower to the protective deck, and will be 6 inches thick throughout.

One torpedo-directing station, 5 inches thick, will be fitted near the conning tower. The directing station for after torpedo tubes will be located in the signal tower.

Teak backing of a minimum thickness of 3 inches will be fitted behind all side and 12-inch turret armor; 2 inches of backing to be fitted behind the 8-inch turret armor; other armor will be fitted without backing.

Athwartship armor of 6-inch uniform thickness will be fitted from the protective to the main deck. The upper and lower athwartship armor to extend from the shell plating to the 10-inch barbettes.

The 10-inch barbettes will extend from the protective deck to about 5 feet above the main deck, and will consist of 8-inch armor in front and 4-inch at the rear below, and 6-inch armor above the gun deck. The barbette and transverse armor will not have any special framing, an efficient connection of the armor to the decks being secured. The 10-inch turrets will have a front plate 9 inches thick, rear plate 5 inches thick, side plates 7 inches thick, and top plates 2½ inches thick. The conning tower will be 9 inches thick, and will have a door 6 inches thick. Signal tower to be 5 inches thick. An armor tube 36 inches in diameter will extend from the base of the conning tower to the protective deck and be 5 inches thick throughout. Teak backing of a minimum thickness of 3 inches will be fitted behind all side armor, and 2 inches thick behind 10-inch turret armor; other armor will be fitted without backing. All the armor will be supplied by the Government.

Protective Deck.—There is a complete protective deck extending from stem to stern, the deck being flat amidships, but sloped at the sides throughout and also at each end. It will be built up of 20-pound lower plating throughout, with nickel-steel of 100 and 140 pounds on slopes and 40 pounds on the flat, except over the magazines, where it will be 60 pounds forward and abaft 10-inch barbettes.

Nickel-Steel Protection.—The following nickel-steel is to be furnished

All the above-mentioned armor will be supplied by the Government.

Protective Deck.—There is a complete protective deck extending from stem to stern, the deck being flat amidship but sloped at the sides throughout and sloped at each end. It will be built up of 20-pound plating throughout, with nickel-steel of 40 pounds on the flat, except it will be 80 pounds forward and abaft 12-inch barbettes over magazines, and of 100 pounds on the slopes.

Nickel-Steel Protection.—The following nickel-steel is to be furnished and fitted complete by the contractor:

Upper strakes of protective-deck plating, as indicated above; hatch covers and gratings in the protective deck; splinter bulkheads on gun deck; sponsons and wing plates for two forward 3-inch guns and for four after 3-inch guns on gun deck; bullet shields between wing plates for 7-inch guns; side protection and wing plates for 3-inch guns on main deck; turret shelf plates; conning-tower base plates; 7-inch gun-port sill plates; 80-pound protection on ammunition hoist trunks not otherwise protected by armor; and 80-pound protection on coaling trunks on slope of protective deck to the height of berth deck amidship.

and fitted complete by the contractor:

Upper strakes of protective-deck plating, as indicated above; hatch covers and grating in the protective deck; splinter bulkheads on gun and main decks; protection to casemates on main deck; sponsons and wing plates for 3-inch guns mounted in sponsons, and 2-inch nickel-steel protection to 3-inch brttery on main and gun decks; bullet shields between wing plates for 6-inch guns; turret shelf plates; conning-tower base plates; 6-inch gun-port sill plates; protection of 80-pound nickel-steel on ammunition-hoist trunks not otherwise protected by armor, and 80-pound protection on coaling trunks on slope of protective deck to the height of berth deck amidships.

The estimated weights of armor and nickel-steel protection is as follows:

	Battleship.	*Armored Cruiser.*
Armor, including wood backing, bolts, etc., tons	3,640	2,200
Nickel-steel, tons	1,031	1,162

Ammunition.—The magazine and shell rooms are so arranged that about one-half the total supply of ammunition will be carried at each end of the ship.

Magazine bulkheads adjacent to heated compartments, such as firerooms, engine rooms, and dynamo rooms, are arranged with ventilated air spaces.

Battle Ships.

Ammunition Supply.—The ammuniton for 7-inch and smaller guns will be conveyed by hoists directly from the ammunition rooms or ammuniton passages to the deck on which it is required, or as near that as possible. These hoists will be driven at constant speed by an electric motor, and will be arranged to deliver not less than eight pieces per hoist per minute.

The number of hoists will be as follows: Twelve 7-inch, fourteen hoists for 3-inch, 3-pounder, and 1-pounder combined, and sufficient whip hoists to the top. To supply the 7-inch hoists, four horizontal ammunition conveyors, operated by electric motors, will be fitted in the ammunition passages for the transfer of ammunition from the handling rooms to the base of the hoists.

The turret guns will have regular turret ammunition hoists, operated by electric power; these hoists leading directly from the handling rooms or the ammunition passages to the turrets. The handling rooms will be isolated from the turrets.

Armored Cruisers.

Ammunition Supply.—The ammunition for 6-inch and smaller guns will be conveyed by hoists directly from the ammunition rooms or ammunition passages to the deck on which it is required, or as near that as possible. These hoists will be driven at constant speed by an electric motor, and will be arranged to deliver at least eight pieces per hoist per minute.

The number of hoists will be as follows: Sixteen 6-inch, fourteen 3-inch, 3-pounder, and 1-pounder combined, and sufficient whip hoists to the tops. For handling ammunition along the passages six horizontal ammunition conveyors, operated by electric motors, will be fitted in the ammunition passages for the transfer of ammunition from the handling rooms to the base of the hoists.

The turret guns will have turret ammunition hoists operated by electric power, leading from the handling rooms to the turrets. The handling rooms will be isolated from the turrets. The turret ammunition-hoist motors and controllers will be installed by the contractor under the specifications of the Bureau of Ordnance.

For transporting 10-inch ammunition, torpedoes and war heads, trolleys and tracks will be fitted in the handling rooms, passages, shell rooms and other spaces as may be necessary.

ORDNANCE WEIGHTS.

	Battleship.	*Armored Cruiser.*
Total ammunition and stores, cruising suply, tons.....	608.3	507.30
Two-thirds ammunition and stores, cruising supply, tons.....	405.5	338.20
Guns, mounts, etc., tons.....	1,063.1	626.43
Ordnance weights on trial, tons.....	1,468.6	964.63

Propelling Machinery.—The engines will be of the vertical twin-screw four-cylinder triple-expansion type, of a combined I.H.P. of 16,500 (23,000), and arranged for outboard turning propellers when going ahead. The steam pressure will be 250 pounds. The stroke will be 4 feet. The cylinder diameters will be sufficient for the required I.H.P. at about 120 revolutions per minute. Each engine will be located in a separate watertight compartment. They will be provided with all necessary auxiliaries and accessories in accordance with the latest practice.

There will be 12 (16) water-tube boilers, placed in 6 (8) watertight compartments. There will be not less than 1,100 (1,590) square feet of grate and not less than 46,750 (48,000) square feet of water-heating surface. The working pressure will be 265 pounds. The length of grates will be about 6 feet 9 (10) inches. The steaming capacity will be such that all steam machinery on board can be run at full power with an average air pressure in the firerooms of not more than 2 inches of water. Generating tubes will be straight and not less than 2 inches in diameter. The provision for removing and renewing tubes, the method of baffling to provide for the proper circulation of the gases, and the facilities for cleaning soot off tubes and baffles must be shown on plans submitted.

All the necessary auxiliaries and accessories will be provided for the efficient working of the boilers.

There will be three (four) smoke pipes, each 100 feet above the base line.

Auxiliary Steam Machinery.—The following auxiliary steam machinery in addition to that pertaining to the main engines and dependencies, is to be supplied: Steering engine; windlass engine; ash-hoist engines for each fire room; forced-draft blowers; evaporating plant, to consist of not less than three units, having a total capacity of 16,500 (23,000) gallons of fresh water per day; a distilling apparatus capable of condensing at least 16,500 (23,000) gallons of water per day.

Miscellaneous Steam Engineering Requirements.—The vessel is to be heated with steam throughout.

The weight of all machinery and tools, stores and spare parts will be about 1,500 (2,060) tons.

Machine Tools, etc.—The following machine tools will be installed in the general workshop. The tools to be run by electric motor or motors.

One screw-cutting back-geared extension-gap lathe; one screw-cutting back-geared lathe; one column-shaping machine; one upright drill press; one sensitive drill; one universal milling machine; one combined hand punch and shears; one emery grinder; one grindstone; six bench vises; one blacksmith forge; all necessary and usual spare parts and tools, will be furnished for machine tools.

Electric Generating Plant.—The vessel will be lighted throughout by electricity. The electric plant will be of not less than 800 (600) kilowatt capacity (no units to be less than 100-kilowatt capacity), driven either by reciprocating engines or turbines, all generators to be of 125 volts pressure at the terminals and disposed in two separate and independent dynamo rooms; six (two) motor generators for power supply to turret-turning motors; 1,150 (1,325) electric fixtures, complete, with necessary incandescent lamps and outlets; two arc lights for each engine room; one arc lamp for each firing position in boiler rooms; twelve arc lamps for coaling booms; six searchlights, at least two of which are to be in excess of 30 inches; two double truck lights with controller; two electric night-signal sets; two diving lamps; ten portable ¼-horsepower electric ventilating sets; fifty (fifty-five) $\frac{1}{12}$-horsepower and twelve ⅛-horsepower bracket fans.

Means of Interior Communication.—All the usual means of interior communication will be fitted, such as telephones, voice pipes, call bells, gongs, annunciators, engine and steering telegraphs, revolution and rudder indicators, heeling indicators, fire alarms, warning signals, alarm signals, turret-hoist indicators, electric log, etc.

A dish-washing machine of approved type will be supplied, driven by an electric motor; also a kneading machine.

Equipment Weights.—The total weight of the steam-driven generating sets complete must not exceed 78.57 (58.93) tons. The total weight of the whole electrical installation, with all fittings, stores, tools, and instruments, must not exceed 186.07

(164.73) tons. The total weight of equipment outfit complete must not exceed 359.68 (336.25) tons.

Electric Auxiliaries.—With the exception of the auxiliaries previously mentioned to be operated by steam, all power on board of the vessel will be electric, including a refrigerating plant with a cooling effect of 4 tons of ice per twenty-four hours, boat cranes, deck winches, turret-turning motors and ventilation blower motors.

Ventilation.—All main compartments of the ship below the gun deck, except the coal bunkers, will be provided with forced ventilation, there being not less than twenty-six blowers, with a combined capacity of not less than 100,000 (110,000) cubic feet per minute. Special attention must be given to spaces subject to habitually high temperatures, such as enginerooms, firerooms and dynamorooms. All blowers, except forced-draft blowers, will be electrically operated.

Coaling Arrangements.—The coal bunkers will be arranged with satisfactory reference to the rapid and efficient supply of coal to the firerooms and have a maximum capacity of about 2,350 (2,000) tons. There will be provided for coaling not less than six winches, twelve booms, and all necessary fixed chutes, scuttles, hatches, and other openings.

There will be three heavy anchors, one of navy type and two of stockless type, and the usual small ones.

Boats.—The following boats will be carried, two (four) electrically-operated boat cranes, the necessary boat davits, and all necessary fittings being provided for handling and stowage:

Battleships.	*Armored Cruisers.*
One 50-foot steam cutter.	One 50-foot steam cutter.
Two 36-foot steam cutters.	Two 36-foot steam cutters.
One 36-foot launch.	Four 36-foot sailing cutters.
Three 33-foot launches.	Two 36-foot sailing launches.
Five 30-foot cutters.	Five 30-foot whaleboats.
Two 30-foot whaleboats.	One 30-foot gig whaleboat.
One 30-foot gig whaleboat.	One 30-foot barge.
One 30-foot barge.	Two 20-foot dinghies.
Two 20-foot dinghies.	One 16-foot dinghy.
One 16-foot dinghy.	Two 16-foot balsas.
One 14-foot dinghy.	Two Carley life rafts.
Two life rafts.	

Complement.—The vessel is designed as a flagship, and provides accommodations for the following complement, viz:

A flag officer.	Nineteen wardroom officers.
A commanding officer.	Ten (eight) junior officers.
A chief of staff.	Nine warrant officers.

Not less than 815 (816) men, including 60 marines.

Water System.—A complete drainage and flooding system will be provided, consisting of a main drain for engine and boiler rooms, secondary drain for all bilges, double-bottom drainage for all compartments within watertight longitudinals, and flooding for all compartments within machinery spaces and for trimming tanks. There will also be installed magazine floods and a complete fire system, with about seventy-five hose plugs; a flushing and salt-water system for ready supply of salt water to all parts of the ship; also a fresh-water system for furnishing fresh water to all spaces required. The total quantity of fresh water carried in ship's tanks will be about 15,000 (18,000) gallons and 2,000 gallons in gravity tanks.

Means of Handling and Navigating the Ship.—Steering stations, with power steering wheels, will be located on the flying bridge, in the conning tower, in the communication room, and in steering-engine room. Hand steering gear will be provided in the steering-engine room.

There will be a lower bridge both forward and aft, and a flying bridge forward.

Masts.—There will be steel masts forward and aft, the foremast having an upper and lower top, the mainmast a lower top only. Masts to be arranged for wireless telegraphy. There will be one signal yard on each mast, also a searchlight platform forward and aft, with a lookout platform on foremast.

Power Doors and Hatches.—There will be approximately 35 (28) sliding watertight doors and six (five) armor hatches which will be worked by power.

Wood Decks.—Exposed main deck, upper deck, top of chart house and bridges will be planked; all planking to be of yellow pine, with teak margins.

Floor coverings of linoleum or wood gratings will be fitted.

The quantity of woodwork will be reduced to the minimum, and no woodwork is to be fireproofed.

The following is the summary of weights to be carried on trial:

	Battleships.	*Armored Cruisers.*
	Tons.	Tons.
Guns, mounts, magazine equipments, etc	1,063.10	626.43
Ammunition, two-thirds cruising supply	405.50	338.20
Steam engineering complete, with water in boilers, condensers, piping, etc., and stores, etc., except stores supplied by the Government, not to exceed	1,500	2,060
Engineering stores supplied by the Government, two-thirds full supply	26.67	26.67
Reserve fresh water for steaming purposes	66	66
Coal, normal supply	900	900
Boats and outfits	51.27	49.68
Masts and spars	31.09	29.31
Equipment complete, including anchors, chains, electric plant, etc., and equipment stores	359.68	336.25
Miscellaneous stores and water, two-thirds full supply	81.32	83.85
Provisions, clothing, and small stores, two-thirds full supply	144.25	106.58
Officers, crew, and effects	109.85	110.55
Total protection, including armor, armor backing, armor bolts, and splinter bulkheads	3,935.23	2,540.67

THE ADMIRALTY AND THE NAVY PROGRAMME.

The Admiralty, it is said, have decided to reduce the Navy programme by not laying down one of four armored cruisers authorized by Parliament, a decision which should not be allowed to pass without some form of public notice, as it sanctions a procedure which may have serious consequences in the future. There is no Government department in which the public take such a keen and intelligent interest as in the Navy, recognizing as they do that on it our security as a nation almost entirely depends. In the event of there being, as is sometimes the case, administrators at the Admiralty, or at the Treasury, more anxious for economy than for efficiency, the medium of Parliament has been the last resort whereby public opinion could assert its power; and if it becomes even possible for a Board of Admiralty to re-

duce the Navy programme as sanctioned by Parliament, then the public voice must necessarily be seriously weakened. Moreover, experience in the past has shown that there is an increasing need for this public safeguard against mistaken retrenchment, so that a protest against the Admiralty decision is now justified. The only hope is that the advent at the Admiralty of Sir John Fisher as First Sea Lord, appropriately enough on Trafalgar Day, will materially strengthen the naval influence against the purely political element, which latter is at times too dominant.

The explanation that will probably be made for the reduction in the Navy programme is the euphemism that the laying down of this armored cruiser has only been "delayed" until next year; but when next year comes, the chances may be that the number of ships which would otherwise have been commenced will not be increased, although one of them may be regarded as representing the vessel now omitted. This is the more likely as it is said that the money which otherwise would have been spent on the building of this cruiser is to be devoted to other purposes connected with the dockyards, notably in the application of a new system of fire prevention, involving a large expenditure. We have no concern here with the need or advisability of applying such a fire-prevention system. We admit even that the expenditure may be well justified; but it can scarcely be said that it will, in the slightest degree, add to the fighting strength of the Fleet. It may further be urged that since the Navy programme was prepared some months ago events in the Far East have affected the balance of naval power. But the loss of Russian and Japanese ships was probably anticipated, and, in any event, the damage was done before Parliament rose. At the beginning of August the Admiralty still regarded the building of four additional cruisers as essential to the maintenance of British naval strength; no event has since occurred in the naval history of the world of such a nature as to explain why, in the course of September, they regard three as sufficient. Furthermore, the two contending countries in the Far East are not the only powers whose naval strength must be considered in determining the necessary additions to the British Fleet; and, finally, the need for cruisers is dependent on

other considerations, notably on the extent of our floating commerce and of our seaboard. We have no wish to refer to the past, or to point out that we continued building cruisers of the protective-deck type when most other nations recognized that side armor afforded greater defence, or that at the same time there was lacking in those protective-deck cruisers the heavier artillery which have since become essential in combat against the armored cruisers of other nations. We are deficient in cruisers with adequate side armor and with powerful primary armament, and because of this the decision now to reduce the Navy programme by one such cruiser is the more serious.

A glance at the comparative qualities of the vessels now projected, as compared with the cruisers of the *Diadem* class, or even of the later *County* class, proves that a reduction, even by one, from the number of later-day cruisers which will be available a year or two hence in the British Fleet is a matter of primary importance. The cruisers of the *Diadem* class, as we have said, have only a 4-inch protective deck, and the thickest armor on the gun positions is 4½ inches, so that they are absolutely incapable of standing up against a cruiser with a modern 7-inch gun, firing armor-piercing or capped projectiles. The first of the *County* cruisers were little superior, as on the broadside they had Krupp steel only 4 inches thick, and the largest gun fitted on board was also in this instance the 6-inch weapon, which is not now reckoned quite satisfactory, even as a secondary gun in cruisers or warships. The later vessels of this class were improved by the fitting of a bow and stern-chasing 7.5-inch gun, while at the same time the broadside belt was increased in thickness to 6 inches. But, owing to the recognition of the advance in gun power, the central part of the latest ships and the gun positions are to be armored with 7-inch and 8-inch carburized steel; at the same time the power of the guns has been very materially increased. The vessels are to be fitted with four 9.2-inch and ten 7.5-inch weapons. The guns, too, are to be of greater length than hitherto adopted, and therefore they will be of higher power than the weapons of corresponding caliber fitted in the previous ships. In other words, there will be in the

new ships four weapons capable of developing an energy of something like 25,000 foot tons, or quite five times the energy possible with the 6-inch guns of the *Diadem*, in addition to ten developing about double the energy of the latter; so that the new cruisers at a range of four miles will be more effective vessels than the *Diadem* or the early *County* vessels at a range of two and-a-half miles. Even at this greater distance, the primary guns of the new ships will collectively do more than double the damage of the fourteen 6-inch weapons in the earlier ships. To make a comparison of the number of cruisers in the British Fleet without attempting to arrive at some unit of fighting strength must be unsatisfactory, and consequently the naval strength three years hence will be more weakened in armored cruisers than is obvious by the mere reduction of one unit. In fact, one of these new cruisers of the *Minotaur* class will equal almost any two cruisers of the early *County* class; others might say that, as regards the *Diadem*, there is no comparison at all.

The new vessels are to have a speed equal to that of the smaller and less powerful vessels—namely, 23 knots. The machinery is not without its interest, as we have here, for the first time, the complete adoption of the water-tube boilers, as recommended by the Naval Boiler Committee. It has not yet, we believe, been decided which of the two types will be adopted. The three vessels to be built are to be constructed in the dockyards at Chatham, Devonport and Pembroke, but the machinery and boilers will be given out to contract, and we understand that the designs submitted to the Consultative Committee are alternatively for Babcock & Wilcox or Yarrow boilers. Although the power in both cases is to be the same (27,000 horsepower), the arrangement of heating and grate surface differs. Yarrow has decided, as a result of very careful trials, that greater efficiency is maintained by minimizing the bar surface of the grates; and in the case of these cruisers the Yarrow boiler will develop 20-horsepower per square foot of grate, as compared with slightly less than 14-horsepower in the case of the Babcock & Wilcox boilers. In the Yarrow boiler, however, the heating surface is much greater, there being an allowance of 3 square feet per in-

dicated horsepower to be developed, as compared with 2.7 square feet in the case of the design for the Babcock & Wilcox boilers. On the Yarrow installation there is a saving of 20 tons in weight, the weights working out to 11.2 indicated horsepower per ton of machinery. The boiler pressure is to be 275 pounds, which will be reduced to 250 pounds at the engines. These will be of the usual four-cylinder triple-compound type, and will run at a piston speed of 1,000 feet per minute when developing full power.

One other matter in connection with the Admiralty attitude towards naval construction must also be raised in connection with the battleships, for the building of which the ship-building firms have this week sent in tenders. Advance must necessarily be step by step towards the highest attainment in this as in every other branch of science, and in offering criticism we may lay ourselves open to the charge of wisdom after the event. But it has been known almost to the ubiquitous "man in the street" that for more than a year there were in existence at the Admiralty designs of battleships conceived with the primary intention of making up deficiencies which had for a long time past been urged against the fighting efficiency of some British vessels. Of course, a warship is a compromise; we have had this put before us very frequently, but there remained the fact that our ships were not equal to expectations in respect of the number of guns of high caliber, and that each gun was shorter than the standard adopted in the ships of several first-class powers. A year ago, when the Admiralty were considering a design for three new battleships, they were strongly urged, both in Parliament and by experienced naval writers, to increase the armament of their vessels. At the last moment the Board, however, decided to adopt the plans of the *King Edward* class, originally prepared nearly three years ago. At that time these vessels were, no doubt, the most satisfactory of their class; but they had ceased to be so in 1903, and where there is no progress there is retrogression. The battleships of this year's programme, two of which are to be built by contract, are superior in respect, especially of gun power and of the distribution of armor, and the question naturally arises as to why, a year ago, the features of this new *Lord*

Nelson class could not have been adopted. In the one case we have four 12-inch and four 9.2-inch guns, with ten 6-inch weapons; while in the newer vessels we have four 12-inch guns and ten of 9.2-inch caliber, and each of the later guns is of greater length, and therefore of considerably higher power. A year ago the 6-inch weapon had been proved defective against modern armor, and to order then vessels of the *King Edward* class with such guns was a retrogressive step. In regard to the smaller weapons, for the repelling of torpedo and submarine-boat attack, the new ships will have a considerably increased battery, there being fifteen guns firing 12-pound shot and twenty-two firing 3-pound shot, with five submerged tubes for the discharge of torpedoes. In respect of armor, too, the new vessels will be superior, the more important parts of the ship being protected by carburized plating of a thickness more likely to exclude shell than the 9-inch armor on the vessels of the *King Edward* class.

One satisfactory feature is that this increased power—the collective energy of the *Lord Nelson's* primary guns will be about 430,000 foot tons, as compared with 272,000 foot tons in the case of the ships of the *King Edward* class—has been realized without materially adding to the displacement tonnage of the ship. There are losses in the balance : one cannot have all the perfections without increased weight or cost ; and here there is a slight reduction in speed and an increase in beam, which latter reduces the number of docks into which the vessel may enter. The naval architect must aim at carrying his weight in the smallest hull, not only because it is desirable to reduce the target, but also in order to decrease displacement. The new ships will be of slightly greater draught than the old, and practically of the same freeboard, but the beam has been increased from 77 feet 9 inches to 79 feet 6 inches, in order that the length may be decreased from 425 feet to 410 feet. A reduction of 15 feet in the length to be protected by armor, &c., is an important gain ; but it is a matter for serious consideration whether such an advantage is not dearly bought when the beam is increased to an extent which will reduce the number of graving docks suitable for the admission of the vessels. Experience during the war has proved that while

the battleship attacked by the torpedo is comparatively safe, the damage done when the vessel is actually struck is so extensive that she must occupy a dock for a considerable period of time, and with vessels of practically 80 feet beam, and only two or three docks capable of admitting them, the situation may become serious.

The new vessels will steam at 18 knots, as compared with the 18½ knots of the *King Edward* class. Here there has been some saving in weight, probably about 170 tons. The speed of battleships is a subject upon which there is a very wide divergence of opinion; there are many who urge that the main thing is fighting power, and the ship that never needs to run away must ultimately win; that on the other hand, the reputed high speeds of warships are more often than otherwise obtainable only under the most favorable conditions. It is assumed that 14 to 15 knots for a battleship, if always obtainable in action, would be quite satisfactory; but Admiral Togo would probably say that if he had had a knot or two more in his ships he might have gained just that advantage in position over the Russian squadrons during their sorties as to have compelled them to fight more frequently, or perhaps even to have prevented their return to Port Arthur. In this respect the actions off Port Arthur must be regarded as typical. The "containing" fleet will always be in danger of losing the victory if the ships are not ready at a moment's notice to intercept an escaping squadron. To have reduced even the top speed of our new battleships, as has been suggested by some critics, would have been a matter involving very grave issues, so that the 18 knots of the new ships, combined with their other qualities, is a very satisfactory rate.

The displacement tonnage is 16,500 tons—a hundred more than that of the *King Edward* ships; but as the speed is slightly less, there is a reduction of 1,250 in the horsepower. The engines otherwise will be practically the same, with a slight reduction, of course, in the diameter of the cylinders, in consequence of the reduction in indicated horsepower. Here, again, we believe that alternative designs have been prepared in connection with the steam-generating plant, and we have in this case also the

same distinctive characteristics in respect of heating surface and grate area. Thus, in the Babcock & Wilcox arrangement, the proportion of heating to grate area is about 35.5 to 1, whereas in the Yarrow boiler system it is nearly 60 to 1. Should both types be adopted in sister ships, as is probable, since the attitude of the Admiralty authorities is to obtain the greatest amount of data on all engineering questions, then the trials of both cruisers and battleships embraced in this year's programme will afford information of a very interesting character.—"Engineering," London.

AN EXPLOSION ON OIL-FUEL STEAMER.

An explosion took place on board the coasting steamer *Geo. W. Loomis*, as a result of which the second engineer was fatally burned, and most of the woodwork of the vessel totally destroyed. The oil-feed pipe leading from the tanks suddenly sprung a leak near the furnaces, causing an explosion. Almost the entire upper works of the vessel were destroyed, and the fact that the vessel is constructed of steel alone prevented her complete destruction by the flames. This vessel, which is comparatively new, was built by the Union Iron Works, San Francisco. She is about 200 feet long, 28 feet beam, and 17 feet hold; 690 gross and 400 net tonnage.

The fuel tank is amidships and is divided into six compartments by a fore-and-aft bulkhead and two transverse bulkheads. At the ends of the tanks are cofferdams 4 feet wide, running from top to bottom, to prevent gas from escaping and reaching the other compartments of the vessel. The tanks capacity is 6,000 barrels of oil, and can be filled or emptied in eight hours.

The *Loomis* has triple-expansion engines developing 400 H.P.; speed, nine knots per hour. She is fitted with the Howden system of forced draft.

The causes of the accident are to be investigated by a marine court of inquiry to fix the responsibility. This disaster will cause greater vigilance than ever to be enforced on all oil burners. The *Loomis* plied in the coast trade between San Francisco

and northern ports, and is to be refitted at once for further service.

A similar disaster of much more serious nature occurred on the *Progreso*, an account of which was given in the JOURNAL, Vol. XV, No. 1, February, 1903, page 272.

THE FUNCTION AND DESIGN OF CRUISERS.

The casual observer of the tendency of cruiser design may be inclined to the view that the essential differences between the cruiser and the line-of-battleship are being steadily reduced; in the matter of cost, for instance, we have now reached one and one-quarter million sterling, while ten years ago the most expensive of our cruisers cost less than half a million sterling; but there can be no doubt that the fighting value has increased *pari passu*. As Lord Selborne pointed out at the launch of the *Black Prince*, however, the student of naval strategy has no difficulty in determining where the cruiser ends and the battleship begins. In the one speed must be achieved even at some expense to the offensive and defensive qualities, while in the other it is of secondary importance. At the same time only physical reasons, and certainly not financial considerations, should determine the degree of forfeiture in respect of gun power and protection in cruisers. Increased cost is justified by the competition amongst the nations, since predominance in the efficiency of each British unit, as well as of the Fleet, is the highest guarantee for the peace of the world. The advance must, therefore, continue, which means that the element of cost must be a subsidiary consideration. This is the more realizable as the Admiralty gets better value for its money from our naval firms than any other government in the world. No one who really appreciates our nation's requirements will complain of the greater expenditure if our ships separately, as well as collectively, represent the highest value obtainable for that expenditure, and are in advance of the attainments of the ships of any other naval power. The launch of the *Black Prince* from the Thames Iron Works affords an opportunity, which should not be lost, of emphasizing this very important fact. The

Black Prince represents the first type of what we hope will be a long succession of vessels, designed by Philip Watts, the Director of Naval Construction, and the occasion suggests a consideration as to whether in this design there is realized to the fullest extent the requirements of modern warfare.

It might seem, from a study of cruiser work during the Russo-Japanese War, as if cruisers would work in squadrons rather than separately; but in this, as in many other instances, it is dangerous to generalize from any particular case. The area of the conflict was greater than many seem to think from a glance at the map; but the volume of floating commerce of the combatants was small. The only merchant ships flying the belligerents' flags within the scene of operations were the Japanese transports, the convoys for which had to be composed of numerous and powerful cruisers, because Russia's "fleet in being"—that working from Vladivostock—was of considerable strength and operated in squadron. Japan had, it is true, to get her supplies from over the seas, but the crippling of the Port Arthur fleet, and the concentration of a watching squadron on the Vladivostock ships, materially interfered with the function of the Czar's cruisers as commerce destroyers. Whether in the event of Britain being at war there would be a squadding of the enemy's commerce-attacking cruisers seems doubtful. Our dependence on over-sea supplies is so great that the number of merchant ships trading to Britain in war time would still have to be very large. Even if the great majority of these sailed under a foreign flag, the excuse for attack so often urged in the present war—that the ship of a neutral power might be carrying contraband—would be so frequently used that the raids of such cruisers would be a source of trouble to the British Navy. If the enemy adopted squadding, the advantage would probably be ours, because it might be possible for a few ships of great power and speed to successfully combat a greater number of units of less individual fighting efficiency. This uncertainty, however, should not greatly influence the general view that British ships, of whatever class, ought to excel any possible enemy in all of the essentials for successful sea fighting.

The war has confirmed the oft-expressed expectation that long range must be the order in future engagements. In the few opportunities presented to Admiral Togo of engaging with his adversaries from Port Arthur, the distance between the combatants seems to have been not less than four miles, and as a consequence 6-inch guns were of comparatively little value. They no doubt succeded in silencing some of the guns in the Russian ships, but this must be attributed in large part to the deficient protection of these quick-firing guns, especially in the cruisers. In the design of the Russian vessels, except in the case of the very latest, the desire has been to instal an enormous number of guns without due regard to the protection of the gun crews; but where, as in other Continental navies, the guns are protected by 6-inch armored casemates or turrets, the same result would not be achieved. Thus, although there are, no doubt, many unprotected ships against which the 6-inch gun would prove effective, it is worthy of consideration whether a designer is justified in placing a large installation of guns of this caliber in modern cruisers, which are expected to be able to "face" any cruiser afloat, and also to be powerful enough to pierce the screen of the enemy's squadron after its position has been located by a fast scout. This latter will be one of the most important duties of our powerful cruisers attached to battleship squadrons, because the high-speed scout will only be utilized for reconnaissance work where force is not to be employed. The more important intelligence as to the strength of the enemy must be discovered by the armored cruiser breaking through the screen, and this may involve very serious fighting.

The 6-inch gun of 50-calibers is undoubtedly a good weapon; it fires a 100-pound shot, which attains a muzzle energy of 6,493 foot tons under the very best conditions; it has the advantage that all operations, including the manipulation of the shot, can be done by manual effort. In service practice nine hits per minute have been achieved, but the average is considerably less. Even if we give it credit for a fighting range of three miles, this gun, using capped shots with direct impact, could only penetrate 3½ inches of the latest cemented armor. As a consequence no

impression could possibly be made on the armor of any first-class cruiser likely to be opposed to it. It is, indeed, improbable that the 6-inch gun, even at the range indicated, could effectually disable a well-designed second-class cruiser. But very few second-class cruisers are now being built, the tendency in all important navies being to confine attention to battleships, first-class cruisers, scouts and torpedo craft. No battleship laid down by a foreign Power last year had a 6-inch gun; Britain alone committed the serious error of equipping some of our ships—the ships of the *King Edward* class—with this weapon. The 6.4-inch guns fitted in some of the later French ships can, with capped shell, penetrate 5 inches of the latest armor; the German 6.7-inch gun, 5½ inches; and the American 7-inch gun, 6 inches—all results comparing with the 4 inches of the British 6-inch weapon.

The *Black Prince* is fitted with ten of these 6-inch guns, along with six of 9.2-inch caliber. This, it is true, is a decided advance on what has been done in previous cruisers for the Navy; yet many naval critics regard this armament as unsatisfactory. The 9.2-inch guns can deal effectively with possible opponents, but for many conflicts the 6-inch gun is of so little avail that the weight involved could have been much more effectually utilized in 7.5-inch or more 9.2-inch guns. Many prefer the entire elimination of the 6-inch gun for the reasons that we have indicated; indeed, such a well-informed, experienced authority on naval construction as Albert Vickers, one of the managing directors of the well-known Vickers Company, in a public speech last week characterized the 6-inch weapon as now obsolete. In battleships he would confine the primary armament to 12-inch guns, and in cruisers to 9.2-inch guns. One cannot help feeling that even the Board of Admiralty recognized that they had made a mistake, because in the four cruisers given out a few months after the *Black Prince* was ordered, they did dispense with the 6-inch guns, changing the armament from six 9.2-inch and ten 6-inch guns to six 9.2-inch and four 7.5-inch guns. This is the only difference made between the class to which the *Black Prince* belongs and the *Achilles* type, of which four are being built. At

first sight it might seem as if four 7.5-inch guns could scarcely equal ten 6-inch guns; but experience in the Far East suggests that energy must be considered even before rapidity of fire and numbers. There will always be occasions when it must be of vital importance to get in as many shots within a given time as is possible; but if the range is to be at least four, and perhaps five, miles, the 6-inch gun cannot do effective work, and its rapidity of fire becomes a useless quality.

With the same velocity the penetration through the most modern armor of the 6-inch gun is 4 inches, as against 6½ inches for the 7.5-inch weapon; so that the latter is capable of dealing by direct impact with the 6-inch armor, with which foreign cruisers are for the most part clad. Sixteen shots per minute, when effective against the armor of the enemy's ship, are certainly more to be desired than even 60 or 70 shots which may be powerless against armor. The 9.2-inch guns, also using capped shell, are capable of penetrating 10-inch armor at the same range—three miles—so that with six guns of this caliber and four of 7.5-inch caliber, the new cruisers are superior to the *Black Prince;* and one cannot but regret that the Board of Admiralty did not realize the full value of the higher caliber at an earlier date, more particularly as the gunmakers of the country took every opportunity of publicly demonstrating the tendency of naval progress. The laying down of the two ships for the Chilian Government early in 1902, in which the 6-inch gun was discarded, ought to have given pause to the Admiralty in their continued appreciation of the 6-inch weapon.

In the cruisers given out this year they have followed the lines of these two Chilian ships. In this *Minotaur* class, of which three are being built, the armament consists of four 9.2-inch guns and ten 7.5-inch guns. The weight involved in this latter combination is slightly greater than in the two preceding ships; but, notwithstanding this, and an increase in engine power and speed, the displacement has only been increased 1,000 tons, as compared with the *Black Prince* and *Achilles* classes. As only twelve months have elapsed since the laying down of the *Black Prince*, with her deficiencies in armament, and the beginning of these

latest ships, with their modern gun power; and as the lessons embodied in this latter class are those which have been urged for three or four years, there is room for criticism of Admiralty administration; and it is to be hoped that the *Black Prince* and the *Duke of Edinburgh* will be brought into line, as far as possible, by the substitution of a few 7.5-inch guns for the many 6-inch weapons.

We may add a short table to show the comparison between these three ships in respect of the three main features. They do not differ materially in armor protection, details of which are given our description of the *Black Prince*. Their auxiliary armament will be practically the same. In size, speed and gun power there has been advance:

	Black Prince.	*Achilles.*	*Minotaur.*
Length between perpendiculars, feet...	480	480	490
Displacement, tons.....	13,550	13,550	14,600
Indicated horsepower	23,500	23,500	27,000
Speed, knots.....	22.33	22.33	23
9.2-inch guns.....	6	6	4
7.5-inch guns.....	none	4	10
6-inch guns.....	10	0	0

The 6-inch 50-caliber gun has a muzzle energy under the best conditions of 6,493 foot tons, the 7.5-inch 50-caliber gun of 11,700 foot tons, and the 9.2-inch 50-caliber gun of 24,190 foot tons —figures which alone demonstrate the immense superiority of the increased caliber. It is true that the larger guns involve more weight, but the increase in power is more than compensation for this. It is a question of strategy rather than of naval architecture; but the designer is ever anxious to attain the highest results, not only in gun power, but also in fighting efficiency and speed.—" Engineering," London.

TURBINE AND RECIPROCATING-ENGINE STEAM-CONSUMPTION TESTS.

A series of trials, which will prove of great value to marine engineers, concerning the weight of steam used in turbine and reciprocating engines respectively, is to be carried out by the

British Admiralty. Two torpedo boats, one of which is fitted with Parsons turbines and the other with ordinary reciprocating engines of the latest type, are to be employed for the purpose. Both these vessels are fitted with Yarrow water-tube boilers, and the boats are practically sister ships. Measuring tanks are fitted to the decks of each vessel. The condensed steam will be pumped into each of these and carefully measured. By this method an approximate comparison of the relative economy of the two systems of propulsion will be obtained, for it will be possible to ascertain the actual weight of steam passing at any stated periods, such as an hour, through the machinery. Every care will be observed to render the records as accurate as possible, so that a practical estimate may be obtained.—" Scientific American."

CONCERNING TUBE CLEANERS.

There are numerous forms of boiler-tube cleaners upon the market at the present time which are actuated by power. Some of these are designed to clean the inner surfaces of the tubes of water-tube boilers, some to remove sooty deposits from the fire side of the tubes of fire-tube boilers, and some to remove scale from the outer surfaces of the tubes of fire-tube boilers; these last acting by striking a succession of blows against the interior of the tube, and thus jarring the scale off from the outside. In the present article we shall not refer to those forms in which the deposits in fire tubes are blown or sucked out by blasts of air or steam, nor to those by which the soot or scale is removed by the action of scrapers that are merely run through the tubes, except in so far as our remarks upon the danger of blowing steam through a cold boiler tube may be applicable to them. What we shall have to say will be mainly confined to those forms in which the apparatus employed communicates to the tube that is being cleaned a series of shocks of greater or less severity, either by directly hammering against the tube or the scale or by the rapid rotation of a cutter or other revolving device which is corrugated or otherwise irregular in shape, and which strikes its blows in

virtue of that irregular shape, the rotation and the centrifugal force by which it is urged out against the tube.

Our inspectors have made numerous reports of serious damage being done to boilers by cleaners of these types, and as the use of such cleaners is becoming increasingly common, we have thought it our duty to call the attention of steam users to the dangers that are incident to them, when they are improperly handled. It should be understood that we have no intention of condemning these power cleaners wholesale, because many of them give very good results when used judiciously and intelligently. Our desire is to direct attention to the precautions that must be taken in the use of such appliances, in order that the good results that they are capable of yielding may be realized, while the bad results may be avoided with corresponding certainty.

The reality of the danger from power-tube cleaners is sufficiently illustrated by actual specimens removed from a boiler upon which a power cleaner had been used. The particular cleaner that was employed in this case is one that hammers against the inside of the tube of a fire-tube boiler, the jar that is thereby communicated to the tube being supposed to rattle the scale off from the outside of the tube. In the instance now under discussion two boilers had been cleaned in this way, and when they were again put in service seven of the tubes collapsed in one of the boilers when the pressure reached 90 pounds. The inspector found that in addition to the seven tubes which had collapsed four others were strongly oval in shape, so that they had to be removed. The cleaner, instead of being constantly rotated and moved along the length of the tube, had been allowed to remain in one position for a short time, so that the hammer had pounded against the tube in one spot, which is indicated by a bright area on the inside of the tube. The result was that the tube was forced out into an oval shape, the greatest bulge coming opposite the bright spot.

The cumulative effect of the blows of a power cleaner of this type, when the cleaner is permitted to remain stationary for a short time, is illustrated not only by the distortion of tubes, but

also by their actual splitting, in severe cases. One of our inspectors has recently reported a case in which three tubes were split in this way in one boiler, from a single application of the tool. In this case the affected tubes were previously in excellent condition, and not sensibly thinned by wear nor by corrosion. The continued and severe action of a power tube cleaner may also actually stretch the tubes longitudinally, so as to loosen them in the heads, and cause leakage and loss of holding power. In one instance, one of our inspectors found that a number of tubes in a boiler that he visited were projecting through the tube sheet at one of the heads by as much as $\frac{1}{8}$ inch to $\frac{3}{16}$ inch, although they had been originally well beaded down to the head. As these tubes were in good condition at the previous inspection, and there was no visible reason for their elongation, the inspector made inquiries for the purpose of discovering the cause of the trouble, and learned from the engineer that a power tube cleaner had been passed through all of the tubes, and that the extension of the tubes had immediately followed its application.

These defects are not confined to cleaners which strike against the inner surfaces of the tubes of fire-tube boilers, but are liable to be observed in any type of power cleaner which operates by repeated concussion upon the tube, or upon such scale as may be attached to the tube. Our inspectors have reported numerous cases, in which water-tube boilers have been badly damaged by the action of cleaners that have been run through their tubes for the purpose of cutting out the scale upon their inner surfaces. In one such report that lies before us, the inspector says: "They had worked on ten tubes in the bottom row of boiler No. 1, but they soon found that one of the headers was cracked, and upon examination it was discovered that every tube into which the cleaner had been passed had crept forward through the front head by from $\frac{1}{32}$ inch to $\frac{1}{4}$ inch. The cracking of the header had been due to this cause, and I did not think that it would be safe to proceed any further with such an apparatus."

In another case "the cleaner was being used under a steam pressure of 100 pounds, and every blow of the hammer left its impression by a dent in the tube." In this instance the pressure

used to operate the tool was undoubtedly very excessive. The pressure should certainly not exceed 50 pounds, and we are of the opinion that 20 pounds is all that ought to be employed. If steam of this tension is not directly available, a reducing valve should be employed, so that the actual pressure furnished to the tool could not exceed a reasonable limit, such as 20 or 30 pounds. Any tube that is scaled so badly that it cannot be cleaned by a pressure of this magnitude should be removed and replaced by a new one. Leakage around the tube ends is a commonly reported result of the use of mechanical cleaners, the tubes being either actually elongated by the blows, as already pointed out, or merely loosened in the heads or headers by the constant succession of shocks to which they are subjected. The extension of the metal is sometimes made evident by the sagging of the tubes, and one report is before us which tells of a case in which the tubes were so stretched that when the boiler was again put into service, certain of them bent up or down until they came in contact with tubes in adjoining rows.

In the case of cleaners whose action involves the discharge of steam into or through the tubes, leakage around the tube ends or the actual extension of the tubes through the heads or headers is liable to be caused by the direct expansion of the tubes, due to the heating effect of the steam. If the tubes and the shell were all heated at the same time and by the same amount, there would be no stresses introduced by the heating; the danger being, not from the heat itself, but from the stresses caused by the fact that the expansion is local, and practically confined to the tube that is being cleaned. It is easy to see that if one tube grows longer from thermal expansion, while the rest of the boiler retains the dimensions that correspond to its lower temperature, there must be a stress of some magnitude thrown upon the tube and upon the heads or headers into which it is secured. The rise of temperature of a tube that is being cleaned by such a device is often considerable, for if a tube is at all foul with scale it may require twenty minutes or so to bring it into proper condition. We believe that some (and perhaps all) of the manufacturers of tools of this kind, being alive to the danger of starting the tubes by

local heating, recommend that the boiler itself be heated up, before setting the cleaner at work, so that the effects of the subsequent warming from the action of the cleaner may be minimized. This practice appears to us to be of doubtful wisdom. In the case of a water-tube boiler the only method of heating the boiler that appears to be at all feasible is to build a light fire under it, while it is dry. If the fire is handled carefully and by a man of good judgment the boiler may perhaps be warmed in this way sufficiently to prevent subsequent injury from unequal expansion, and yet without being itself injured by the direct action of the fire; but we should hesitate to recommend such a measure for general employment, because we should fear that the average attendant could not be depended upon to always strike the somewhat nice medium at which the warming of the boiler is effective, while the boiler itself is not overheated in any part by the fire. Moreover, the remedy would hardly be effective in any case, unless the slow fire were maintained during the entire time that the tubes are being cleaned. If the boiler were heated up only at the outset, for example, then it is evident that if from ten to twenty minutes are spent upon each tube the majority of the tubes in the boiler would have ample time to cool down before the cleaner reached them. If, on the other hand, the slow fire were maintained during the entire time of cleaning, there would be a correspondingly greater danger that at some part of this period the fire would either become so light as to be ineffective or so heavy as to overheat some part of the boiler. It will be observed that we do not assert that these things cannot be done, and done rightly; but our experience indicates that it is not well to recommend, for general adoption, any procedure whose safety and efficacy presuppose that the attendant will do everything with good judgment. We know too well that boiler attendants are human, and that they, like other mortals, do not always do things in the way they should. It is far better and safer to avoid the discharge of steam into a cold tube altogether, and to operate the cleaner with compressed air. This is sometimes inconvenient, but it is better to go to a little trouble and expense rather than to take chances of injuring the boilers. Of course it is unneces-

sary to say that there is no objection to the use of steam in those forms of power cleaners which are operated by motors external to the tube, and in which the exhaust does not enter the tube.

In review of what has been said let us state: (1) That when power tube cleaners are used they should be kept in motion, so that they cannot strike a succession of blows against any one part of the tube; (2) they should be operated by a pressure not exceeding 20 pounds, or, at the most, 30 pounds per square inch; (3) steam should not be permitted to blow through the tubes of a cold boiler for a sufficient time to sensibly heat the tubes; (4) compressed air should be used to operate tube cleaners, unless the motive power is entirely external to the tube; (5) in any case the boiler should be carefully watched during and after the application of a power cleaner, especially around the ends of the tubes and on the headers, and at the first sign of distress of any kind the use of the cleaner should be promptly discontinued; (6) lastly, a power cleaner should never be put in charge of any attendant save one upon whose judgment and skill the owner of the boiler can implicitly rely.—"The Locomotive."

THE CONDITIONS OF WARSHIP TRIALS.

The explanation offered by the naval engineer for occasional breakdowns of the machinery of warships and for inability to attain the results achieved on the official contract tests, is usually that the conditions observed when the machinery is tested are more conducive to satisfactory performances than those obtaining in the service, and especially under war regulations. In a few instances this is probably a full explanation; in other cases we fear it is made, and is accepted, with the consciousness that there are no definite means of verifying its accuracy. The Admiralty have at last decided to put the matter beyond cavil by specifying for all future ships that contractors' trials must be run under war conditions, which, as we shall presently show, are very onerous as applied to untried machinery. Some firms have protested that the difficulties of such a course are too great. Several firms have, however, been induced to conduct the official trials under the new

conditions, although this was not an item in their contract, and although the engines were not designed with this important change of procedure in view. The first ship to carry through her official tests under this arrangement is the *Dominion*, built by the Vickers Company, and the results are, therefore, of exceptional interest. Their significance can only be appreciated by a review of the whole subject.

First, in justice to the Navy Department, it should be stated that breakdowns of warship machinery are no more frequent than is the case with merchant ships, and are less frequent than is the experience with other navies. The only difference is, perhaps, that more is heard of them in the daily Press, while in technical papers more is written of them, as they often raise important questions in dynamics and mechanics. Recently, too, the failures of new ships to attain, after commissioning, the same results as were realized on contractors' tests, have been the exception rather than the rule. They have occurred usually in large cruisers with powerful machinery embodying departures from previous practice. Warship trials have in the past been conducted with little or no limit so far as number of men in attendance was concerned; and the same remark may be applied to stores, excepting only coal. In the case of lubricating oil, for instance, the amount used on some trials was far in excess of the quantity available on commission—the storage capacity required for such an amount of oil would be prohibitive. It may be easy to run machinery at full power, even if the lubricating system is not as perfect as it should be, so long as oil may be poured over crank and crosshead and main bearings, on guide surfaces, or thrusts, without stint; whereas if the supply were limited to the flow through service pipes, attention would be directed to the defects in the arrangements made for distributing lubricants. Naval officers urge that most of the defects due to mechanical causes are attributable to this one reason.

There are other defects, which, although latent during contractors' trials, develop afterwards, when the engines have been subjected to further stresses while in commission. In a large number of cases bearings have given trouble. Many such in-

stances are due to defective arrangements for supervision when the vessel is in commission, or to an insufficiency of experienced officers, and not to initial faults in design. But there are many parts of an engine in which defects may be latent, only to discover themselves in time. As typical sources of trouble, there may be instanced piston-rod packings and white metal in bearings. Difficulty often arises immediately after the ship is commissioned and the frequent refitting of the piston-rod packings keeps the engine-room staff busy and anxious. All bearings feel the stress of use. If the white metal has not been properly fitted in the first instance, it will gradually work loose, crack and split, and lead to heating, especially where the brasses have not been "tinned" so as to ensure the white metal and the brass shell being in absolute close contact or solid. Many contractors omit this tinning, being content to hammer the white metal solid. This lasts through the contractors' trials, and perhaps, for a few months of the commission; but it is apt, sooner rather than later, to give trouble. Inferior white metal is another cause of disappointment. All specifications provide for chemical analyses, but although this may establish perfection in the composition, trouble may arise owing to the overheating of the metal when it is run into the bearing, as under those conditions it becomes gritty. These are the material defects stated in defence of the naval engineer; we are not concerned for the moment with the personal equation.

With the view of assimilating the conditions observed on contractors' trials with service working, the Admiralty has specified the following conditions to be observed in all ships built in the future: 1. No water is to be used on the bearings during trials. 2. The service oil tanks and other service fittings only are to be used for the supply of oil. 3. The total clearances between bearings are not to exceed certain limits. 4. The number of persons employed on duty either in the enginerooms or looking after all the work in the boilerrooms, except firemen, is not to exceed a certain limit. This includes the foreman and chargemen, but not the company's representative in charge. 5. The hatches, doors and valves, automatic or otherwise, below the

armored deck, are to be closed as soon as the anchor is off the ground, and not to be opened until the anchor is let go again, except in the following cases: (*a*) For purposes of ventilating for half-an-hour in a day, or for so long as the captain may consider necessary. (*b*) In such parts of the ship, whereever necessary, where men who are employed are sleeping. In cases (*a*) and (*b*) men should be stationed so that these openings could be closed if so ordered. 6. The doors between the engineroom and stokeholds are to be kept closed. 7. All bunker doors are to be closed, with the exception of those from which the coal is being worked, and, if required, one communicating door to one adjacent bunker only; but, wherever possible, such bunker doors are to be kept closed.

We may consider these conditions *seriatim*. As to the use of water on the bearings we have seen on trials great variations in practice, even in sister ships engined by different firms. In one case no extra water was used; in the other fire hose with a good pressure made it advisable to wear oilskins and sou'-westers in the engineroom. The latter condition may be justifiable in the stress of a running fight, where everything depends on a speed in excess of the best formerly attained; but for the designed power it must be regarded as abnormal. The importance of limiting the supply of oil has already been dealt with. In the matter of clearances the Admiralty have now prescribed for battleship engines, in the case of main bearings, the limit should not exceed $\frac{30}{1000}$ inch; in crossheads, $\frac{20}{1000}$ inch; and crankheads, $\frac{25}{1000}$ inch. In cruisers with higher piston speeds and lighter shafts these limits are still less. These, we think, conform with the best practice. With true alignment, well-prepared surfaces, accurate machinery and efficient means of lubrication, there should be no difficulty in running the machinery with these limits. In the *Dominion* the corresponding maximum clearances were respectively $\frac{27}{1000}$ inch, $\frac{16}{1000}$ inch, $\frac{21}{1000}$ inch. We have known in naval work of limits quite equal to double these figures. The difficulty is that with wide limits trouble arises owing to sudden and frequent variations in the speed of ships working in squadrons.

Difficulty presents itself in connection with the number of men engaged in the engineroom during the trial. It will be conceded that new machinery, practically untried, demands more vigilance, especially with the limitations as to oil and water, than engines which by long running have disclosed their faults or established their trustworthiness. The contractors, however, are free to have as many preliminary trials as they choose. In the case of the *Dominion*, a battleship with engines of 18,000 indicated horsepower, there were only two runs prior to the official tests, one on the way from Barrow-in-Furness to the Clyde and the other a spin of six hours' duration on the day preceding the trials. The builders' experience of warship machinery and the confidence which comes from a long series of successes, however, induced them to embark on a series of trials, two of thirty hours' duration and one of eight hours' duration, which were carried out between Thursday and Tuesday in irreducible time and with uniformly satisfactory results. The engineroom staff on the thirty-hours trial was limited to 22 and on the full power trial to 29, numbers determined by a consideration of the working in three shifts by the service complement of the ship. The boilers were worked entirely by the naval stokers with chief stokers in charge of each boiler room, supervised by officers. The service complement will include 1 engineer commander, 2 lieutenants or sub-lieutenants, 3 artificer engineers, 3 chief engineroom artificers, 12 engineroom artificers, 7 chief stokers, 17 leading stokers, and 120 stokers. On trials of similar ships of about the same horsepower fifty to sixty men have been engaged on contractors' trials, many of them certificated sea-going engineers. The *Dominion* has proved that in this respect also the new condition has been fulfilled, although it will be conceded that the measure of responsibility is greater.

The closing down of the machinery spaces, as stipulated in the conditions 5 to 7, is a still more serious item, so far as the contractors are concerned. When orders are given in service for general quarters—the war condition—they involve the closing down of all doors, &c., and in ordinary steaming attempts are now being made to work under those conditions. It has, however,

long been an ambition of the naval designer to approximate to the ideal state so far as the armored deck is concerned; and as far back as the early seventies trials were made in the old *Vanguard* with a closed-in engineroom. The results were satisfactory, but there was lacking the courage necessary to carry the scheme out with permanent armored decks over the engineroom, with its difficulties as to ventilation and supervision. As to the former, the experience in the *Dominion* is encouraging. For each engineroom there are four sirocco fans—two of 25-inch diameter, for supplying air, and two of 30-inch diameter, for exhausting air, the former at the after corners, and the latter at the forward end, where the heat is greatest. These run at 400 revolutions, and supply 15,000 cubic feet per minute. From the supply main there are delivery trunks to various levels; and, so far as concerns the lower part of the engineroom—below the level of the cylinders—the temperature was from 90 degrees to 100 degrees Fahrenheit; but above this it was greater, attaining in the vicinity of the high-pressure cylinder a maximum of 130 degrees Fahrenheit. The external temperature was 50 degrees Fahrenheit, at night, and 59 degrees Fahrenheit, in the shade, by day. Thus only on the oiling, &c., platforms, where work is intermittent, did the temperature reach an abnormal height. The restrictive regulation, of course, greatly hindered supervision. This is inevitable; but in war it is always the lesser evil that must be chosen. It is important to provide against attack by shell and torpedo, and this closing down is the only available preventive measure; in peace supervision is the primary consideration. In war the case must be met by more experienced and skilful men in each department. On the *Dominion's* trial Vickers' staff was adequate, so that even from this standpoint the conditions have been proved amply realizable.

The duration of trials continues as before. Ten years ago a change was made; then the continuous steaming speed (usually regarded as at three-fourths of the total power) was only required for 4 hours, while in the succeeding 4 hours full speed had to be maintained. But it was arranged, when water-tube boilers were introduced, that, following upon the 30-hours' trial at one-

fifth, or cruising power, there should be a 30-hours' trial at 75 per cent. of the total power, with an 8-hours' run at full power. At the beginning of the new system a day or two usually elapsed between succeeding trials; but with the *Dominion*, as in one or two earlier ships, the intervals were only a few hours—7½ hours in one case and 20 hours in the other. The trials specified by foreign navies are less stringent. In the United States the full-power trial is only of 4-hours' duration, and there is, in addition, a 24-hours' trial at 66 per cent. of the full power. In France the full-power trial is of the same duration as in the British Navy, with a 24-hours' trial at cruising speed. In the case of Japan there is a full-power trial of 6 hours, including 4 runs over a course of at least ten miles in length. In Russia there is a run of from 2 to 6 hours duration at full power, and with the coal consumption carefully measured. There is also a trip of 2 to 6 hours at quarter power, the coal consumption being noted to determine the radius of action. Between the two runs the fires may be cleaned, but the engines and boilers must not be touched. For the large ships of the German Navy the conditions of trial are usually—(1) one 6-hours' run at maximum capacity; (2) one 24-hours' run at seven-tenths full power, the coal burned being weighed; (3) one 24-hours' run at about two-tenths full power, and with the coal weighed.—"Engineering," London.

STOKING INDICATORS FOR TIMING THE FIRING OF FURNACES.

There are doubtless but few sea-going engineers who have not realized the danger of relying too much upon the intelligence of the stoker for the regular firing of the boiler furnaces at stated fixed times. Any mechanical arrangement or method presenting the advantages of careful, systematic and regular firing in such a way as to relieve the engineer of this portion of his numerous responsibilities must surely be very welcome. With this object the Kilroy stoking indicators, which are now successfully at work on several warships, have been devised. It is claimed that this

apparatus secures a maximum coal efficiency and a minimum of smoke production.

The system provides in one ship a number of stoking indicators, one for each stokehold or row of boilers. The indicators ring a loud gong, and show the number of furnaces to be fired at the required intervals and in definite rotation, all the indicators being actuated electrically by one regulator or timing apparatus conveniently placed in the engineroom. The boiler furnaces, or, more strictly speaking, the furnace openings, should be numbered, preferably with brass numbers, as painted or chalk numbers are easily obliterated.

The regulator or timing apparatus consists of a special switch mechanism, which, at uniformly recurring intervals of time, closes electrical circuits, which actuate the indicators. This switch mechanism is so designed that but one indicator is rung at a time, calling for but one furnace door to be open at once in any group of boilers. A regulating lever is provided to enable the engineer to vary the rate of firing. For instance, if the regulator be set to an eight-minutes' interval, and supposing that there are eight furnace openings in a stokehold, the indicator will show a new number and ring a bell every minute; so that a complete rotation is obtained once in eight minutes. A set of switches is provided, one for each indicator, so that only those indicators which are required need be switched into gear. The apparatus is strong and watertight, and when once switched into gear is automatically operated and requires no attention.

Each indicator consists of a strong outer case protecting the bell, and an inner watertight case containing the electro-magnet and mechanism for moving the dial, which has numbers on it corresponding to the boiler furnace openings. When the current is passed round the electro-magnet, one armature is attracted, so as to ring a single stroke on the bell, which is made watertight in the same manner as an ordinary single-stroke admiralty-pattern bell. The other armature is attracted at the same time, and its motion serves to move the dial round to show the next number through the aperture in the front of the case; so that every time a furnace has to be fired a loud bell sounds and the num-

ber of the furnace appears. This number will remain visible until it is time to fire the next furnace.

As a rough guide for determining the quantity of coal needed at each firing, the following may be taken as a typical case; assuming that each boiler is to be worked at an output of 450 I.H.P. and that the coal consumption is 2 pounds per I.H.P. per hour, then the coal burned per boiler will be 900 pounds per hour; and taking the weight of a shovelful of coal as 10 pounds, this is 90 shovelfuls in 60 minutes for each boiler. When 8 minutes has been decided upon as the firing interval, the number of shovelfuls required for firing to each boiler is therefore $\frac{90 \times 8}{60} = 12$. If each boiler has two furnace openings this will mean six shovelfuls to each furnace opening every time its corresponding number appears on the indicator. If each of these openings has two doors this will, of course, be three shovelfuls on each quarter of the whole furnace.

The advantages claimed for the apparatus, which is patented and made by Evershed and Vignoles, Chiswick, London, W., are the following: (1) It is less complicated and much less delicate than a clock mechanism, if used for the same purpose. (2) It lends itself to being set at speeds varying over a large range without complication. (3) The forces used are larger, thus enabling a quick make-and-break switch of adequate proportions being brought automatically into action. (4) The current taken is very small, being only .6 ampère on an 80-volt circuit; of this, .2 ampère go to work the regulator, and .4 ampère for the stoking indicators, when all the indicators are in use.—"Marine Engineering."

A VOYAGE WITH BELLEVILLE BOILERS.

Notwithstanding the report of the Navy Boiler Committee, the many engineers, constructional and naval, who were satisfied with the Belleville boiler, when well constructed in the first instance and properly supervised in service, have not receded from their position, and no one who associates with naval boiler constructors and with engineers afloat having experience of this steam gen-

erator, can fail to be impressed with the continued confidence expressed in the type. This view has been intensified by the letter sent to the Admiralty by Admiral Sir Compton Domvile along with the report of the committee, in which he indicated that he was "compelled" to say that his experience with the Belleville boilers on the Mediterranean station, where he is in chief command, had been very favorable to them as steam generators, and that no serious boiler defects had been experienced in any of the ships. This state of affairs has continued, and for some months there has been almost an entire cessation of the little defects which were so largely magnified by the daily press, to the disadvantage of the water-tube steam generator. The explanation is probably that which we have repeatedly urged, namely, that with experience in manufacture, and especially with due regard to the enormous change involved in stoking and in general working, better results can be achieved. Engineering officers in the Navy now realize that more care is necessary, and we hope also that there is a better appreciation on the part of the executive officer in control, of the importance of allowing sufficient time in harbor for an examination of the boilers and the rectification of little defects which threaten a breakdown.

A voyage recently made by the first-class cruiser *Terrible* from England to Wei-hai-Wei, and home, affords very strong evidence of the possibilities not only in respect to economy, but in steady working of the Belleville boiler when satisfactorily equipped and controlled with due regard to its peculiarities. The *Terrible*, it may be remembered, was built some eight or nine years ago at the Clydebank Works, now owned by John Brown & Co. This vessel and the *Powerful* were the first large vessels of the Navy to be fitted with the Belleville boiler, although prior to this very satisfactory results had been attained with the same type of steam generator in the gunboat *Sharpshooter*. In these two cruisers many of the difficulties associated with a radical change had to be met, and since valuable lessons are more frequently learned through failure than otherwise, it resulted that in their earlier years these vessels gained, rightly or wrongly, an ill-repute amongst those opposed to change generally in naval

engineering. The boilers no doubt suffered more because of this extensive experimental work; but the voyage now made by the *Terrible*, after having had her boilers overhauled, clearly shows that this type of steam generator may give satisfactory results under favorable treatment. The success in the French, Russian and Japanese navies of the same boiler has further established this view.

The *Terrible* left England on July 1 of this year, with orders to steam at from 12 to 12½ knots, and arrived at Wei-hai-Wei on August 24. During this time she steamed 10,645½ nautical miles, at an average speed of 12.4 knots, and there was used 5,005 tons of coal for all purposes, including harbor expenditure. The home voyage was made with equally satisfactory results; after only being six days at Wei-hai-Wei she left for England, arriving here on October 19. The distance steamed on this occasion was 11,095.6 sea miles, with a consumption of fuel, for all purposes, of 5,087 tons. Thus on the double voyage, made in about 3½ months, she covered 21,741.1 nautical miles, at an average speed of 12.6 knots, with a coal expenditure of 10,092 tons. These are the general facts, which will be appreciated by every one connected with long-distance steaming. We have no desire to make comparisons with ships having any other type of boiler, but it is a strong commentary on the importance of having the boilers in satisfactory condition and under experienced managment, that two years ago the same ship, with a draught of 1 foot less, and at a speed of 0.8 mile per hour less, required for the single journey from Wei-hai-Wei to England—11,045.8 miles—more coal than was needed for the double voyage this year. In other words, two years ago only 1.55 miles were traversed for each ton of coal used for propulsion purposes, while this year the average distance steamed, out and home, per ton of coal was 3.37 sea miles.

Upon investigation of the details of this very remarkable voyage, we elicited some facts of interest. The speed throughout varied very little from first to last; but, in conformity with regulations, the periodical high-speed trials were made on the voyage between Colombo and Aden. The vessel has forty-eight boil-

ers, which are all required when the full power of 25,000 indicated horsepower is necessary; but throughout this voyage the number of boilers in use varied from fourteen to twenty, according to the position of the coal. All of the boilers are not of the same capacity, which explains the variation in the number of boilers for the very slight variation in speed. The results showed that the average coal burnt per square foot of grate per hour was 14 pounds. We give in tabular form the principal results of the voyage:

TABLE I.—PERFORMANCE OF H.M.S. *TERRIBLE* ON VOYAGES FROM ENGLAND TO WEI-HAI-WEI AND BACK.

——	1904. Outward voyage.	1904. Homeward voyage.	1904. Double voyage.	1902. Homeward voyage.
Mean draught on voyage, feet and inches	28–0	26–5¾	27–3	26–7
Total distance steamed, knots	10,645¼	11,095.6	21,741.1	11,045.8
Total coal used, including harbor expenditure, tons	5,005	5,087	10,092	11,163
Mean indicated horsepower	4,330	5,054	4,692	5,738
Average speed, knots	12.4	12.8	12.6	11.8

In such a voyage a considerable proportion of time is always spent in harbor, when a part of the coal consumption continues. On the outward voyage, which occupied in all 55 days, the vessel was steaming 35 days, so that she was in harbor something like 20 days altogether. The homeward journey occupied 50 days, but the actual steaming time was again almost exactly 35 days. In 1902 the voyage occupied 59 days, and during this time the vessel was steaming 39 days; the proportion of time in harbor to the time steaming did not thus differ materially. This year the vessel was even a longer time out of dry dock than prior to the 1902 voyage, and therefore the hull was not quite in the same state as was the case two years ago. The draught, as we have shown in our first table, was considerably greater this year. But notwithstanding all this, an increased speed of 1 mile per hour was got for quite 1,000 indicated horsepower less power. That the boilers gave a very much higher economy is proved from the fact that the coal consumption for the main engines works out at

1.78 pounds per indicated horsepower per hour for the double voyage this year, as against 2.9 pounds two years ago. In other words, the ship steamed on an average 2.34 sea miles for every ton of coal used for all purposes on board, including that for harbor use, as compared with 1.22 sea miles two years ago. But if the fuel used for main engines only be calculated, then the distance traveled per ton, as we have already said, was 3.37 sea miles, as compared with 1.55 sea miles two years ago.

It is very interesting to note the use to which the coal is put on such a voyage; only about 80 per cent. being used when the vessel is actually at sea, and only 60 to 70 per cent. for propulsion purposes:

TABLE II.—COAL USED ON H. M. S. *TERRIBLE* IN VOYAGES BETWEEN ENGLAND AND CHINA.

—	1904. Outward voyage.	1904. Homeward voyage.	1904. Double voyage (includ'g fractions)	1902. Homeward voyage.
Total used, including harbor expenditure, tons..	5,005	5,087	10,092	11,163
For steaming, tons	3,043	3,391	6,434	7,086
For auxiliaries, tons	733	926	1,659	704
For distilling, tons	194	165	359	258
For all purposes at sea, tons	4,428	4,853	9,281	9,007
For main engine, pounds per I.H.P. per hour	1.8	1.7	1.78	2.9
For all purposes, pounds, per I.H.P.	2.6	2.49	2.57	3.7
Per square foot of grate, per hour pounds	13.4	14.7	14	17.3

The total quantity of water distilled during the round voyage this year was 2,900 tons, as compared with 1,784 tons in the single voyage two years ago.

The satisfactory nature of the performance of the ship will at once be appreciated from an examination of the figures which we have published, and ought to reassure public opinion as to the Belleville boiler. We have no intention of entering into a controversy as to the relative advantages or efficiency of various types; it is sufficient to say that since so many of our ships have been fitted with Belleville boilers, there is no need whatever

to adopt any pessimistic view as to their efficiency; in fact, we are quite satisfied that, when well managed, the Belleville boilers in the British Navy will in war service give at least quite as good results as the same type of boiler in the Japanese ships, and more need not be asked for. The performance of the *Terrible* itself proves this. It is due, in large part, to the experience of Engineer-Commander Arthur W. Turner, the chief engineer, who, it is worth recalling, was the first British naval engineer to have charge of Belleville boilers at sea, as he was on the gunboat *Sharpshooter*, a vessel which, as we have pointed out, was the first unit of the British Navy fitted with this type of generator.—"Engineering," London.

THE JAPANESE ENGINEER IN WAR.

We have given frequent illustrations of the ability with which the Japanese have taken advantage of the applications of Western science to develop, in little more than a generation, their country from a state of feudalism to that of a constitutional Power with a rapidly-increasing industry and commerce, and with all the appliances of a modern nation. The example of Japan shows how the work of the engineer, when properly applied, and with full national consciousness of the objects in view, can revolutionize economic and social conditions. Probably this is the chief lesson which Japan has to teach the peoples of Europe and America, who for the most part have been content to look at the work of the engineer from a strictly individualistic point of view. They, in general, still hold to the belief of Adam Smith, that Nature has made provision for social well-being by the principle of the human constitution which prompts every man to better his condition; the individual aims only at his private gain, but in so doing is "led by an invisible hand" to promote the public good, which was no part of his intention. The Japanese have discovered that the national consciousness is a most important factor in national evolution, and this discovery in great part accounts for the great developments which have taken place during the past thirty years. The discussion of this subject would

take us far beyond what are considered engineering topics, and we merely mention it that engineers and statesmen may be induced to take a wider view of its operation than they usually do.

Notwithstanding all that has been written about Japan, people in the West have still a very inadequate idea of the importance of the functions which engineers have performed in Japan. That importance is fully recognized by all thoughtful Japanese. In a book recently published (Alfred Stead, editor,) there has been gathered together the opinions of distinguished Japanese on the different aspects of national life. Regarding engineering, Marquis Ito says: "On the occasion of my second visit to London as one of the ambassadors of our country, it was suggested to me that it would be most beneficial to establish a special engineering college in Japan, where every branch of engineering should be taught. Such a college would be unique, no other nation having one. The idea seemed a very good one, and on my return to Japan I took the necessary steps, and, with the assistance of foreign professors, we founded an engineering college, now incorporated in the Tokio University. From this institution have come the majority of engineers who are now working the resources and industries of Japan. I consider the establishment of this college as one of the most important factors in the development of Japan of today."

The engineers of Japan have been the chief agents in developing the resources of the country, and raising it from a state of feudalism to one of industrial and commercial activity. They have improved the roads, built railways and telegraphs, have developed the shipping and the Navy, and applied their engineering knowledge to those industries which were best capable of development in their country. Most important of all, they have made Japan strong and able to resist foreign aggression. This was clearly shown in the war with China in 1894–5. The sound of the Japanese cannon at the mouth of the Yalu River awoke the peoples of the world to a sense of the fact that a strong nation had arisen in the Far East, which would exercise a profound influence in the Pacific area. Meantime the engineer has been at work elsewhere, and the completion of the Trans-Siberian Rail-

way has brought Russia and Japan face to face, and the clash of two conflicting civilizations and national ambitions has brought about a war which is destined to mark a new epoch, not only in the history of the Far East, but probably also of the world. We cannot, of course, enter into the politics of the war or the details of the events connected with it; our present object is simply to indicate how the Japanese engineers, although they have not taken an active part in the actual fighting, have done most important service, and made the operations of the Army and Navy effective.

Without the work of the engineer the Japanese would have been impotent, either for offence or defence. During the present war the railways which have been built in Japan have been fully utilized to convey men and materials to the coast, and the ships of the mercantile marine have been busy in transporting them oversea. The telegraphs have been used to communicate instructions and to keep the authorities informed regarding movements and requirements. The dockyards and shipbuilding yards have been ready to undertake repairs, and the arsenals and machine shops to turn out war materials of all kinds, as well as appliances which aid operations in the field. Light railways have been laid down on the way to battlefields, and wireless telegraphy and telephones to convey instructions to the soldiers; in short, all the latest applications of mechanical, electrical and chemical science have been freely and intelligently used. In all these departments the Japanese have not simply copied from Western nations; they have adapted and improved. Even in the navy they can now give many lessons to Britain. While in naval matters they accepted all the guidance the Western world could give them, at the same time they struck out a line of their own, and the fleet which they have created is unique in the character of its units. British designs have in many respects been improved upon, with the result that the Japanese have obtained in their latest ships many features which have won the admiration of the world. Among the inventions which have added materially and conspicuously to the fighting efficiency of the navy may be instanced the gunrack of Rear Admiral Yama-

nouchi, the water-tube boiler of Engineer Admiral Miyabara, the smokeless powder of Dr. Shimose, the percussion cap of Vice Admiral Ijuiu, the floating mine of Commander Oda and Captain Tawada, and several others which might be mentioned all of great practical utility in real warfare. The Japanese naval officer is a highly-trained scientific man, and a survey of all the conditions shows that the success of the Japanese Navy is not of a haphazard nature, but is the result of systematic training, combined, of course, with the fearless bravery of the officers and men.

No doubt naval officers in all the navies of the world will extract many useful lessons from the actions of the Japanese Navy in the present war. Admiral Sir Cyprian Bridge, G. C. B., has expressed the opinion that "the strategy was admirable and has been completely successful, notwithstanding that no important ship has been destroyed by the locomotive torpedo, though some, since repaired, have been injured by it, and that neither sunken steamers nor mines have effectually blocked up Port Arthur." To go into the naval aspects of the war would, however, take us beyond the object of this article. All, however, will agree with what Lord Selborne, the First Lord of the Admiralty, said in Parliament some time ago, namely, that he attached the greatest importance to the quality of the *personnel*, and he insisted that the officers and men were of more importance than the ships.

What has been said of the Japanese naval officers might also be said of the officers of the army, although they have not the same opportunities for the display of engineering skill. Japanese military officers devote themselves absolutely to their profession, living for nothing else, and are fearless of death. Their strategy is carried out with all the skill of a game of chess, and their conduct generally proves that the real measure of the importance and even of the power of a nation is to be found ultimately in the quality of its people. The guiding principles enunciated by the Emperor when he ascended the throne have always been kept in mind, not only by himself and the Government, but also by the people, and the national policy has been directed to the attainment of the objects in view. Education, industry, the Army

and Navy, foreign politics, in short the national life, were subordinated to the attainment of these objects. This is the great secret of the success of Japan.—"Engineering," London.

A RECORD IN ORE UNLOADING.

A new world's record for the rapid handling of iron ore has been established during the present season of navigation upon the Great Lakes. In the making of the new record the former one was cut straight in two, an accomplishment of no little moment in the industrial world. By the working of two kinds of modern ore machines at one time in the new steamer *A. B. Wolvin*, nearly 10,000 tons were removed in four hours and a half.

Soon after the launching of the new steamer *Wolvin* last spring, an article appeared in the "Scientific American" descriptive of the distinctive features of that ship which were expected to work something of a revolution in ore handling. Chief among these was mentioned the hopper bottom, which admitted of keeping the ore at all times within reach of the automatic clam-shell buckets; also that the length of this hopper, without division, is 409 feet. This construction has come up to all expectations in facilitating the work of loading and unloading.

The new record was made at Conneaut harbor, the port which has in recent years been noted for its wonderful machinery and its notable records. The work of unloading was started at 7·22 in the morning and was completed at exactly 11·52. The total delay in the continuous operating of the machines did not exceed five minutes. Eight machines were used in all, four of the Brown machines, which are fitted with clam-shell buckets, and four of the Hulett machines, which are the automatic ore unloaders with the ten-ton buckets. In all the vessel has thirty-three hatches. As soon as one machine finished a hatch it was transferred to another without a moment's delay. Officials of both the dock and the machine companies were on hand to witness the test and to assist in avoiding the slightest impediment. The exact amount of ore removed was 9,945 tons. The

Hulett machines removed 169 carloads of the total of 226 which the boat contained.

The former record was held by South Chicago, where a similar cargo was removed from the *Wolvin* soon after it entered the ore trade. Ten and a-half hours were required for the unloading operations at that time. The vessel was under the machines for fifteen hours, of which four and a-half hours were lost. Fifteen machines were used.

Of interest in connection with the records of the *Wolvin* is the announcement which has been made this fall that four vessels still larger than the *Wolvin* are to be built for the Pittsburg Steamship Company, which is the lake end of the United States Steel Corporation. These vessels are to be 569 feet over all, 540 feet keel, 56 feet beam, and 31 feet deep. Their construction will be of the arch system, resembling that of the *Wolvin* and *Sahara*. There will be thirty-four hatches and no bulkheads in the hold. The four vessels will cost more than $1,500,000 and are to be completed by the first of next July.—W. Frank McClure, in "Scientific American."

TORPEDO BOATS FOR MANILA.

A fleet of torpedo boats is to be subjected to an unsually severe test when five of these vessels will soon start on a cruise to the Philippines, a journey more than half around the world. Never before has there been an expedition by torpedo boats which, in the distance to be covered and the difficulties to be encountered, compares with the prospective voyage of this flotilla.

The torpedo boats selected are the *Bailey*, *Barney*, *Biddle*, *Porter* and *Dupont*, from the reserve flotilla of the Navy. The largest is the *Bailey*, which was built at Morris Heights, New York City. She is 205 feet long, 19 feet beam, about 7 feet draught, 280 tons displacement, 5,600 horsepower, 30 knots speed.

The *Barney* and *Biddle* are sister ships, both built at Bath, Me., 157 feet in length, 18 feet beam, 175 tons displacement. These vessels developed more than 28 knots speed on their trials and

have reached 30 knots on short runs. The *Porter* and *Dupont*, built by the Herreshoffs, are 175 feet in length, 18 feet beam, and are as speedy as the other twin craft, which, though smaller, are of more recent construction. During the Spanish-American war the *Dupont* steamed 12,000 miles without being laid up for repairs.

This journey will be a test of the torpedo boats, and only in less degree a trial of the health and strength of the officers and men on board. Service on a torpedo boat is the severest exaction which is to be found in naval life, and for that reason not only young officers but young men for the crew are selected for these vessels.

The question of coal supply is one of the problems which confront the naval officers who have in hand the planning of this protracted voyage, but it is argued that with their steaming radius of more than 3,000 miles there is no danger in sending this flotilla across the Atlantic and the Indian Ocean and up the Pacific Coast.

The proposal to send torpedo boats to the Orient is the result of the success which last winter attended the sending to the Far East of a flotilla of torpedo-boat destroyers. These were the *Decatur*, *Dale*, *Barry*, *Bainbridge* and *Chauncey*. The destroyers are considerably larger and stauncher than the torpedo boats, and the more daring project now proposed will doubtless arouse even more widespread interest.—"The Marine Journal."

SUBMARINE BOAT *PROTECTOR* APPROVED.

The War Department has received the report of the Board of Officers, appointed to witness certain tials of the submarine boat *Protector*. The conclusions and recommendations of the Board are as follows:

For the defence.—First and second.—The Board believes that this type of submarine boat is a most valuable auxiliary to the fixed mine defence, and, in cases where channels cannot be mined owing to depth, rough water, swift tides, or width of channel, it will give the nearest approach to absolute protection now known

to the Board. The boat can lie for an indefinite time adjacent to the point to be defended, in either cruising, awash or submerged condition, by its anchors or at the bottom, ready for instant use, and practically independent of the state of the water, and in telephonic connection with the shore, or can patrol a mined or unmined channel, invisible to the enemy, and able to discharge its torpedoes at all times. It possesses the power of utilizing its engines in every condition except the totally submerged, and can always charge its storage batteries while so doing, necessitating its return to shore only when gasoline must be replenished. In narrow channels the boat or boats would have a fixed position with a telephone cable buoyed, or anchored at the bottom. In wide channels they would patrol or lie in midchannel or where they could readily reach approaching vessels.

Third.—As a picket or scout boat, outside the mine field or even at extreme range of gunfire, telephone communication can be sustained and information received and instructions sent for attacking approaching vessels.

Fourth.—The test at Newport demonstrated the ease with which the boat can locate and pick up cables, and, with minor alterations in the present model, junction boxes, etc., can be taken into the diving compartment and repaired at leisure, while absolutely protected from hostile interference. The faculty possessed by the boat, of maneuvering on the bottom and sending out divers, leaves little or nothing to be desired in its facilities for doing this work.

For the attack:—The boat shows great superiority over any existing means of attacking mine fields known to the Board.

First.—It can run by any mine field, as at present installed, with but little or no danger from the explosion of any particular mine or from gun fire, during the few seconds it exposes the sighting hood for observations, and can attack at its pleasure vessels in the harbor.

Second and third.—The Board personally witnessed the ease with which cables can be grappled, raised and cut while the boat is maneuvering on the bottom; mine cables can be swept for, found and cut, or a diver can be sent out for that purpose.

The Board recommends consideration of the foregoing by the General Staff. The question of the use of the Whitehead torpedo as part of the fixed mine defences, fired from tubes on shore, is now receiving consideration. Where channels are wide and water swift this use of the Whitehead will be very limited. With boats of this type the Whitehead can, it is believed, be carried within certain effective range in all ordinary channels, and this alone will warrant the consideration asked for. The Board recommends, in consequence of its conclusions, that five of these boats be purchased for use in submarine defence.

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

The twelfth annual convention of the Society of Naval Architects and Marine Engineers was held in New York on Thursday and Friday, November 17 and 18, 1904, at which the following papers were read:

Simple Methods in War Ship Design a Necessity; by George W. Dickie, Esq., Member of Council.

The Semi-Globular Naval Battery; by Anson Phelps Stokes, Esq., Associate Member.

The Sea-Going Battleship; by Commander William Hovgaard, Royal Danish Navy, Member.

Some Recent Experiments at the U. S. Model Basin; by D. W. Taylor, Naval Constructor, U. S. N., Member of Council.

Some Further Notes on the Performance of the Torpedo Vessels of the United States Navy at Sea; by Lieut. L. H. Chandler, U. S. N., Associate.

The U. S. Armored Cruiser *Colorado;* by Asst. Naval Constructor, J. M. Powell, U. S. N., Associate Member.

Coaling War Ships at Sea—Recent Developments; by Spencer Miller, Esq., Member.

Time Allowance for Steam Yacht Races; by Rear Admiral George W. Melville, ex-Engineer-in-Chief, U. S. Navy, Vice-President.

On the Rules of Lloyd's Register for Building Yachts to Class; by George Stanbury, Member.

The Position of the Center of Lateral Resistance; by L. E. Burtin, Esq., Member.

Subdivision of Weights in Ships' Displacement; by Nabor Soliani, Member.

Maintenance of Machinery in Merchant Ships; by Robert Haig, Esq., Member.

Uniform Specifications; by W. D. Forbes, Esq., Member of Council.

High-Speed Gasoline Launches; by Clinton H. Crane, Associate.

Speed and Power of Recent Motor Boats of Several Types; by Alpheus A. Packard, Member.

Recent Launching Practice of the Atlantic Coast; by Assistant Naval Constructor R. H. M. Robinson, U. S. N., Member.

Recent Launching Practice of the Pacific Coast; by Everett P. Lesley, Esq., Junior.

SHIPS.

UNITED STATES.

Connecticut.—Launch of.—The battleship *Connecticut* was successfully launched at the Brooklyn Navy Yard, September 29, 1904, at 11·30 A. M.

The *Connecticut* is a sister ship of the *Louisiana*, both vessels being authorized in 1902.

The vessel is of steel throughout; trial displacement, 16,000 tons; maximum displacement of 17,770 tons; length on the load-water line, 450 feet; over all, 456.4 feet; 76.10 feet beam; 24.6 feet draught. The engines will be of the twin-screw, vertical, four-cylinder, triple-expansion type, with a combined horsepower of 16,500, designed for a speed of eighteen knots. There will be three funnels, two military masts, two main and four secondary turrets and a main-deck central battery. The total weight of armor is 3,992 tons. On each side amidships there is a steel belt 193 feet long, 9 feet 3 inches wide and 11 inches thick. Forward and aft of this belt is another, 9 inches thick, covering the magazines. This is ended by 6-inch bulkheads. On the lower deck for 284 feet the armor is 6 inches thick, and on the main deck for 236 feet abreast of the central battery, the armor is 7 inches thick. The protected deck is 1½ inches thick on the flat and 2½ inches on the slopes. The main turrets (2) are 8 inches thick, with 12½-inch faces. The barbettes are covered with 10 inches of armor, and the secondary turrets with 6 inches of armor with 6½-inch faces. The conning tower is protected with steel armor 9 inches thick, and the signal tower with 6 inches of steel.

The armament will consist of four 12-inch breech-loading guns in pairs in two turrets, one forward and the other aft, and eight 8-inch guns in pairs in four turrets on the superstructure. In the main-deck battery there will be twelve 7-inch rapid-fire

guns. In addition, there will be twelve 14-pounders, twelve 3-pounders, six 1-pound automatic guns, two 1-pound semi-automatic and eight .30-inch machine guns. In the magazines will be carried 60 rounds for each 12-inch gun, 100 rounds for each 8-inch gun and 7-inch gun, 500 rounds for each 3-inch gun, 600 rounds for each 3-pounder, and 960 rounds for each 1-pounder.

The coal-bunker capacity is 900 tons (normal), but this can be increased to 2,200 tons. Ordinarily, she will carry sufficient coal to steam 7,000 miles at 11 knots, or 2,500 miles at 18 knots. The *Connecticut* is to be fitted as a flagship, and when in commission will carry 42 officers and 761 men. The amount to be expended for this vessel is not to exced $4,212,000, the sum authorized by Congress.

Nebraska.—LAUNCH OF.—The battleship *Nebraska* was successfully launched October 7, 1904, from the shipyard of the Moran Bros. Company, Seattle, Washington.

A notable incident was the premature launching of the vessel eleven minutes before the official hour set, due to some unforeseen strain, occasioned by the wedging-up process.

This vessel is one of the *Virginia* class, described in the JOURNAL, Vol. XVI, No. 2, May, 1904, page 676.

The general dimensions are: Length on load-water line, 435 feet; beam, extreme, 76 feet 2½ inches; draught, on normal displacement of 14,987 tons, 23 feet 9 inches; draught, greatest, full load, about 26 feet; designed indicated horsepower, 19,000; speed, 19 knots; complement of officers, 40; complement of seamen, marines, etc., 772.

Georgia.—LAUNCH OF.—The battleship *Georgia* was launched successfully from the Bath Iron Works, Bath, Maine, October, 11, 1904.

An unusual feature of the launching showing the progress made in the installation of the machinery of this vessel, was that the boilers and smoke-stacks were in position and steam was up. This vessel is the fourth of the five battleships of the *Virginia* class to be launched. Reference to the general dimensions of this class will be found above, under the *Nebraska*.

New Jersey.—LAUNCH OF.—The battleship *New Jersey* was

successfully launched November 10, 1904, from the works of the Fore River Shipbuilding Company, Quincy, Mass. This vessel is a sister ship to the *Rhode Island*, building by the same contractors, which was launched May 17, and is the last to be launched of the *Virginia* class just referred to.

Milwaukee.—LAUNCH OF.—The *Milwaukee*, a 22-knot protected cruiser of 9,700 tons displacement (of the same class as the *Charleston*, described on page 333, JOURNAL, Vol. XVI, No. 1, February, 1904,) was successfully launched from the Union Iron Works, San Francisco, Cal., September 10. The ship is 424 feet long on the load-water line, 66 feet extreme breadth, and 22 feet 6 inches normal draught. Her launching weight was about 5,000 tons. On board were the tubes for all boilers, erected in position, also line and propeller shafting, but no propellers—the shafts being protected by cast-iron caps.

The two sets of main engines of the *Milwaukee* are of the usual four-cylinder, triple-expansion type, 36, 59½, 69 and 69 by 54 inches stroke. At 133 revolutions they are expected to develop 21,000 I.H.P., sufficient to drive the ship at 22 knots. Steam is carried at 250 pounds per square inch. Both engines turn outboard. Each condenser has 13,400 square feet of cooling surface, and a 21-inch centrifugal circulating pump and compound engine. Two auxiliary condensers for engine rooms have 600 square feet of cooling surface each. The dynamo-room condenser has 1,200 square feet of cooling surface.

The steam is furnished by sixteen Babcock & Wilcox boilers having a total grate surface of 1,400 square feet and a total heating surface of 64,000 square feet. The Howden forced-draft system is used, air being supplied by sixteen compound blower engines running at 800 revolutions. There will be four smoke pipes, with four up-takes each, and air heaters complete. A very complete outfit of pumps is installed with cross connections for interchangeable duties in case of emergency. Other auxiliaries include ash hoists, turning engines, ice machinery, work shop, distilling plant, ventilation system and minor auxiliaries, including a very complete equipment of electric ammunition hoists.

The main battery consists of fourteen 6-inch breech-loading

R. F. rifles of 50 calibers in length. The secondary battery includes eighteen 3-inch (14-pounders) breech-loading rifles of 50 calibers in length, twelve 3-pounder semi-automatic guns, four 1-pounder automatic guns, eight 1-pounder R. F. guns, two 3-inch field guns, two machine guns, .30-caliber, and eight automatic guns, .30 caliber. An armor belt 4 inches thick is worked in amidships, while a protective deck 3 inches on the slopes and 2 inches on the flat extends the entire length.

In the central electric station are two 100-kw. and three 50-kw. generators, furnishing current at 125 volts for 1,000-odd lamps, twelve arc lamps, six 30-inch searchlights, fans, electric whistle, etc. The ship will be steered by steam, and fully equipped with telephones, speaking tubes, signal and general alarm systems, and a wireless telegraph equipment.—Extracts from "Marine Engineering," October, 1904.

West Virginia.—TRIALS OF.—The armored cruiser *West Virginia* underwent successful speed trials over the Cape Ann Course on November 2, 1904, during which she developed an average speed of 22.146 knots for the four hours of this full-power trial. Full data of her performance will be published in a later issue.

Pennsylvania.—TRIALS OF.—The armored cruiser *Pennsylvania* ran a very successful four-hours' full-power speed trial on November 23, 1904, over the Cape Ann course, averaging for the four hours a speed of 22.436 knots per hour, with a reported coal consumption of 2.2 pounds per horsepower per hour. The full data for these trials will be of unusual interest for comparison with the results for vessels of this type, and will be given in detail in a later issue.

Tennessee.—LAUNCH OF.—The first-class armored cruiser *Tennessee* was successfully launched from the works of the William Cramp & Sons' S. & E. B. Company, Philadelphia, Pa., December 3, 1904.

This is the first to be launched of the two vessels of this type now building; the sister ship, the *Washington*, will probably be launched in the latter part of February, 1905. Their general dimensions are similar in many respects to those of the *Pennsyl-*

vania class (6), trial data of which will be found in this issue, in full for the *Colorado*, and in brief for the *West Virginia* and *Pennsylvania*. The beam of the *Tennessee* and *Washington* is about three feet greater than for the *Pennsylvania* class and their displacement is also greater by about 1,100 tons, but, owing to better underwater form it is expected that the contract speed of 22 knots will be obtained on about the same total horsepower as required for the *Pennsylvania* class.

General Characteristics.—Length on load-water line, 502 feet; length over all, 504 feet 6 inches; beam, molded, 72 feet 6 inches; trial draught, 25 feet; trial displacement, 14,500 tons; speed, 22 knots; coal to be carried on trial, 900 tons; bunker capacity, 2,000 tons.

Armament:—Four 10-inch B.L. guns, 45 calibers long; sixteen 6-inch R.F., 50 calibers long; twenty-two 3-inch (14-pounder) R.F.; twelve 3-pounder semi-automatics; two 1-pounder automatics; two 1-pounders, R.F.; two 3-inch field guns; two machine guns, .30 caliber; six automatics, .30 caliber.

Armor.—A complete water-line belt, 7 feet 6 inches wide, 5 inches thick over engine and boiler spaces, and tapering to 3 inches at ends, extends the entire length of vessel. For a length of 232 feet, the side of the vessel above the water-line armor will be protected by 5-inch armor extending vertically over the main-deck space. At the ends of this 5-inch armor are transverse armored bulkheads 5 inches thick. The 6-inch guns are protected by 5-inch armor. The 10-inch guns are mounted in elliptical, balanced, electically-controlled turrets, 9 inches thick in front, 7 inches at sides, and 5 inches at rear. The barbettes for 10-inch guns are 7 inches thick in front and 4 inches thick at rear.

There is a 9-inch conning tower and shield, a 5-inch armored tube, and a protective deck of nickel-steel extending throughout the vessel, 1½ inches in the flat, 4 inches in thickness on the slope. Along the sides above the protective deck extends a cellulose belt.

Propelling Machinery.—There will be two vertical, inverted-cylinder, direct-acting, triple-expansion engines designed to develop 23,000 I.H.P. when making about 120 revolutions per

minute. The diameters of cylinders and their order from forward are: Forward L.P., 74⅛ inches; H.P., 38½ inches; I.P., 63½ inches, and after L.P., 74⅛ inches. The engines are arranged for outward-turning propellers when going ahead.

There are sixteen water-tube boilers of the Babcock & Wilcox marine type, placed in eight watertight compartments. Total grate surface, 1,650 square feet; heating surface, 70,944 square feet.

Paducah.—LAUNCH OF.—The gunboat *Paducah* was successfully launched from the yard of the Gas Engine and Power Co. and Charles L. Seabury & Co., Consolidated, Morris Heights, New York, October 11, 1904. The *Paducah* and her sister, the *Dubuque*, were authorized for service in Central and South American waters. Both vessels are 174 feet long, 35 feet beam, and have a draught of 12 feet 3 inches. Their armament consists of six 4-inch rapid-fire guns, four 6-pounder guns, two 1-pounder guns, and two Colt automatic guns.

Naval Programme Proposed by the General Board.—The General Board of the Navy has recommended, for presentation to Congress, the following increase of the Navy for the coming year: three battleships, five scout cruisers, six torpedo-boat destroyers, six torpedo boats and two squadron colliers, at an aggregate maximum cost of $41,300,000.

The Board suggests that the battleships shall follow the general type of the *Connecticut* class, partly to provide the homogeneity which it urges as a need of the Navy, and in part because of the general commendation of that type, both here and abroad. This would give the Navy nine first-class battleships of 16,000 tons displacement, and of practically identical design. The estimate given for these battleships is about $8,000,000 each, giving a total of $24,000,000 recommended for new battleships.

Great speed is urged as the feature of the five scout cruisers, two million dollars being the estimated limit of cost of each of these ships. In character they will follow the general lines of the *Chester*, *Birmingham* and *Salem*, which will have a displacement of four thousand tons.

The Board thinks the six torpedo-boat destroyers and the six

torpedo boats recommended should have greater size and seaworthiness than previously-built vessels of this class.

The Board suggests that the new destroyers be so constructed that they can make long cruises with the battleships without need of repairs, and can travel with ease in a rough sea, even if this necessitates a reduction of speed.

The new colliers have a proposed displacement of 12,500 tons, and a speed of about sixteen knots, to enable them to keep up with a battleship squadron at cruising speed.

Scout Cruisers.—BIDS FOR BUILDING.—A date will soon be set for the opening of bids for the construction of the scout cruisers *Chester*, *Salem* and *Birmingham*, as the Navy Department has approved the chief characteristics of the vessels. Length of these ships between perpendiculars will be 420 feet; breadth, 46 feet 8 inches; draught at full load, 18 feet $3\frac{1}{2}$ inches; depth amidships, 36 feet $5\frac{5}{16}$ inches; displacement, loaded, 4,310 tons; draught on trial, 16 feet 10 inches; displacement on trial, 3,750 tons; speed, 24 knots; battery, twelve 3-inch guns, two 21-inch submerged torpedo tubes. They will carry 3,600 rounds of ammunition for 3-inch guns and eight torpedoes. The estimated weight of battery and full load of ammunition is 140 tons. The length of the machinery space will be suitably protected by $1\frac{1}{2}$ inches to 2 inches of upright, nickel-steel, armor, supplemented by protection plates around hatches and steering engines. There will be at each end a nickel-steel bulkhead 1 inch thick. The steering gear above the water line will have nickel-steel protection 2 inches thick on sides and 1 inch on top. The scouts will be fitted with four ammunition hoists for the 3-inch guns. Accommodations will be provided for one commanding officer, ten wardroom officers, five warrant officers and 368 men. The ships will carry reciprocating engines with about 16,000 H.P., and will be fitted with all the usual and necessary auxiliaries. The boilers will be of the *Express* type having about 690 square feet of grate surface and about 37,000 square feet of heating surface. The total machinery weight to be allowed will be about 780 tons.

The design prepared by the Department provides only for

reciprocating engines, owing to the difficulty experienced in obtaining reliable preliminary plans or proposals for such installations, from the turbine manufacturers of this country, which could be safely embodied in the type plans. There will be, however, a provision for the consideration of alternative plans submitted by bidders in which preference will be shown to those designs embodying turbine installations for propelling machinery, all other features being equal.

ENGLAND.

Dominion.—STEAM TRIALS OF.—The first-class battleship *Dominion*, built by Vickers Sons and Maxim, at Barrow-in-Furness, completed, November 2, the steam trials prescribed by contract. The results from every point of view were thoroughly successful, the speed attained at full power was, on a deep-sea course, 19.5 knots—one nautical mile per hour greater than was anticipated in the design; so that, excepting the *Triumph* and *Swiftsure*, she is the fastest battleship in the fleet, which, in view of her 16,400 tons displacement, and her powerful primary armament—four 12-inch and four 9.2-inch guns—is specially satisfactory. The power realized was 18,438 indicated horsepower—438 indicated horsepower over the contract requirement, notwithstanding that the machinery was worked under war conditions, with closed-in engine room and other restrictions, never before exacted on contract tests. The coal consumption at full power was 1.77 pounds per indicated horsepower per hour for all purposes, while the water consumption for the main engines—17.3 pounds per horsepower hour—showed a satisfactory efficiency. The trials, themselves of sixty-eight hours' duration, were carried out in four days.

The *Dominion* belongs to the *King Edward VII* class, and has a length between perpendiculars of 425 feet, a beam of 77 feet 9 inches, and a depth molded of 42 feet 11 inches. At a draught of 26 feet 9 inches she displaces 16,400 tons. She has a belt, extending from the after armored bulkhead forward to the ram, 9 inches in thickness for the greater part of the length, reduced in three stages at the forward end to 2 inches. The maximum thickness extends along the citidal from 5 feet below the load

line to about 3 feet above it; the next strake is 8 inches, and the top strake 7 inches, the latter reaching to the upper deck. The 12-inch guns are in barbettes of 12-inch armor, with hoods having sloping sides. The 9.2-inch guns are mounted separately in turrets of 7-inch armor on the upper deck—one at each quarter. The 6-inch guns are mounted within the 7-inch broadside armor in a concentrated casemate, as introduced first by the Vickers Company in the *Mikasa*. These 6-inch guns—five on each broadside—are on the main deck of 2-inch armor, while the upper deck is of 1-inch. On convenient positions for defence against torpedo-boat attack, are fourteen 12-pounders, fourteen 3-pounders and 2 Maxims. The armament includes also four submerged tubes for firing torpedoes.

Military tops have been dispensed with; but on the masts there have been constructed large observation stations which will carry Barr and Stroud range finders, and from these stations the guns will be trained and directed. The after navigating bridge has been abolished, although towers for searchlights still remain. There is, however, an admiral's bridge immediately abaft the main navigating station—a feature more usual on foreign war ships. As to ventilating cowls, the sails tried a year or two ago have been discarded, and the shafts to stokeholds, &c., are now fitted with mushroom-shaped covers, which can be raised and rotated on roller bearings. For the boat derrick on the main mast vertical hydraulic engines are now substituted for the horizontal machines, not only because they require less deck room, but they are more efficient. The conning tower is larger; steam-heating pipes and radiators are laid throughout the habitable quarters; baths are provided for all classes, and more attention has been paid to mechanical ventilation, especially in 'tween decks, as no port holes are possible in the armored sides of the vessel.

The engines are—as has been the case in battleships built since the *Duncan* class ordered in 1898—of the cruiser type, with four cylinders arranged on the Yarrow-Schlick-Tweedy system. The high-pressure and intermediate cylinders, respectively 33½ inches and 54½ inches in diameter, have piston valves, and the two low-pressure cylinders at the fore and aft end of the sets are 63 inches

Steam Trials of H. M. S. "Dominion".

Date of trial	October 28 and 29.		October 29, 30, 31.		November 1.	
Nature of trial	30 hours at 3,600 I.H.P.		30 hours at 12,600 I.H.P.		8 hours at 18,000 I.H.P.	
	Forward.	Aft.	Forward.	Aft.	Forward.	Aft.
Draught of water, feet and inches	26–1	26–8	26–5¾	26–11¼	26–0	27–3
Speed of ship, knots	By log, 12.8		By log, 18.3		19.5 measured course.	
Steam pressure in boilers, pounds per square inch	241.3		243.8		248.1	
Air pressure in stokeholds, inch	Nil.		1/16		9/16	
	Starboard.	Port.	Starboard.	Port.	Starboard.	Port.
Vacuum in condensers	26.5	26.3	26.5	26.2	25.5	25.6
Revolutions per minute	78.3	77.5	113.9	113.7	125.8	125.5
Mean pressure in receivers:						
High	124.6	124.5	200.6	198.8	228.1	227.5
Intermediate	26.6	25.5	64.5	61.6	84.3	83.1
Low	1.6	1.9	11	11.4	21.7	21
Mean pressure in cylinders:						
High	35.5	38	79.5	80.1	90.7	91.5
Intermediate	14.9	14.4	33.9	32.7	40.6	41.3
Low forward	6.57	6.21	13.06	13.6	19.6	19.3
Low aft	6.18	4.89	14.2	13.3	22	20.6
Mean I.H.P.:						
High	561	630	1,934	1,945	2,434	2,453
Intermediate	660	631	2,186	2,108	2,885	2,934
Low forward	390	364	1,125	1,174	1,865	1,831
Low aft	366	287	1,223	1,148	2,086	1,949
Total	1,977	1,912	6,468	6,375	9,270	9,168
Grand total	3,889		12,843		18,438	
Consumption of coal per I.H.P. per hour, pounds	1.93		1.68		1.77	
Total loss of water per 1,000 I.H.P. per 24 hours, tons	5.34		3.04		3.38	
Water consumption per I.H.P. per hour:						
Main engines, pounds	16.6		16		17.3	
All purposes, pounds	21.6		18.4		18.3	

in diameter, with double-ported flat valves. These have balancing rings, and throughout the trials a vacuum of 20 inches was maintained behind them. The stroke of the engines is 48 inches, and the connecting rods are 8-feet centers. The ordinary double-eccentric link motion is applied, the reversing gear being of the all-round type common to naval work, with a double-cylinder steam engine. All working parts are of forged steel, the crank-shafts being 17½ inches in diameter, with a 9-inch hole, the thrust and line shafts, 17 inches, with a 9½-inch hole, and the propeller shafts 20½ inches, with an 11½-inch hole. The propellers, which are entirely of bronze, have four blades of 17 feet 6 inches diameter, with a pitch on trial of 18 feet 6 inches, and a developed surface of 86 square feet. All auxiliary machinery is independently driven, excepting the air pumps, which are two in number for each set of main engines, driven from the intermediate and high-pressure crossheads. There are four main condensers, with a total cooling surface of 19,000 square feet. The other auxiliary appliances include four evaporators, with an output collectively of 180 tons per 24 hours, and two distillers, having a total cooling surface of 107 square feet, to provide 45 tons of fresh water per 24 hours.

The boilers are of the Babcock & Wilcox type, sixteen in number, with 3½-inch tubes, the total heating surface being 47,369 square feet, and the grate area 1,402.5 square feet. There are four fire doors to each boiler, and, as there are three boilers in a row in the aft and midship stoke holds, there are twelve furnace doors to be fired, the interval being three to five minutes. The firing was done only through one door in each boiler successively, so that the interval of renewing any portion of the fire in each boiler was five minutes. The cleaning of each section of the fire was at regular intervals of two hours, so that the entire grate in each boiler was cleaned every eight hours. Regularity in stoking and cleaning was ensured by clocks at each boiler, having an outer disc divided into sections to suit the intervals of firing—36 per hour. There is no steam-reducing valve. The feed pumps are located in each stoke-

hold, and the water for the main engines was measured in a series of four tanks placed temporarily on the upper deck, independent tanks being provided for the auxiliary service. As shown in the table of results, the water consumption per indicated horsepower per hour in the main engines was, on the thirty hours' trial at one-fifth power, 16 pounds; at 75 per cent. power, 16.6 pounds; and at full power, 17.3 pounds. When the auxiliary engines are included, there is apparently less economy at the lower powers; but this is due to the fact that then the auxiliaries are proportionately of much greater power to the total indicated horsepower than when the engines are working at their highest speed. This same remark applies to the loss of water, which, on the higher power trials, was from three to four tons per 1,000 indicated horsepower per 24 hours. This, however, had to be made up by the distillers, and the coal consumption is debited accordingly.

The table gives full details as to the engine performance. Everything proved most satisfactory, notwithstanding the onerous conditions called for, this being the first ship to carry out her trials under the new regulations.

A brief analysis of the power performance is given in the appended table:

—	Thirty hours at one-fifth power.	Thirty hours at seven-tenths power.	Eight hours at full power.
Heating surface per indicated horsepower of main engines, square feet.	4.58	3.69	2.56
Coal consumed per square foot of firebar surface, pounds	12.2	16	23.4
Indicated horsepower per square foot of firebar surface	7.4	9.15	13.15
Indicated horsepower per ton of machinery	...	...	10.63

As regards speed the results are very satisfactory. Six runs were taken on the mile at Skelmórlie, with the following results:

Number.	Time on mile.		Speed in knots.	Revolutions.	Indicated horsepower.
	min.	*sec.*			
1	3	24⅓	17.630	112.75	12,976
2	3	16⅔	18.310	117.60	13,094
3	3	20	18.000	114.60	12,652
4	3	24	17.647	111.70	12,420
5	3	30⅔	17.110	109.45	12,345
6	3	19⅓	18.018	114.70	12,414

This gives an Admiralty mean speed of 17.79 knots, with 113.4 mean revolutions per minute and a mean indicated horsepower of 12,650. The vessel was run for 30 hours, and the mean speed by log worked out at 18.3 knots. The speed taken from actual distance covered on chart was 18.24 knots, the mean indicated horsepower for 30 hours being 12,843.

On the eight-hours' full power trial it was impossible, owing to fog, to obtain runs over the measured mile; but runs were made on a sea course, and the speed obtained from point to point bearings, and worked out at 19.5 knots. This mean indicated horsepower for the eight hours was 18,438, and mean revolutions 227.8.

New Battleships.—LORD NELSON CLASS.—The orders for the two battleships included in the Navy Programme of 1904–5 have been placed. One of these is to be built at the new works at Dalmuir-on-Clyde, of William Beardmore & Co., and the other at the works of Palmer's Shipbuilding and Iron Company, Jarrow-on-Tyne. These battleships mark a large step in advance, especially in respect of gunpower and of armor protection. The armament of this new *Lord Nelson* class includes four 12-inch and ten 9.2-inch guns. The length of the guns has been increased—the former from 40 to 45 calibers, and the latter from 45 to 50 calibers. The 9.2-inch guns will be mounted, eight of them in pairs, within gunhouses over the upper deck, while the two remaining weapons will occupy central positions on each broadside. It is important to note that thus none of the guns will be placed at a lower level than the upper deck, while the machine guns, numbering fifteen 12-pounders, twenty-three 3-pounders and two Maxims, will be mounted on the central battery behind, and at

a higher level than, the main guns, so that they will command the whole sea area within torpedo range of the battleships. As regards armor, the more vital parts of the ship will be protected by broadside armor of greater thickness than has yet been adopted since the latest quality of carburized steel was introduced, 12-inch steel being more extensively adopted than hitherto. The side armor extends from five feet below the water line to the upper deck, which level is also armored in the vicinity of the guns, and this side protection extends, although of reduced thickness, forward to the ram. There will be five submerged torpedo-firing tubes. The Palmer ship will be fitted with Babcock & Wilcox boilers, and the Beardmore ship with Yarrow boilers. The machinery for this latter ship is to be constructed by Hawthorn, Leslie & Co., Newcastle-on-Tyne, under sub-contract with the builders. The engines are to be 16,750 indicated horsepower, each engine having a high-pressure cylinder of 32¾ inches, an intermediate of 52¾ inches, and two low-pressure cylinders of 60 inches in diameter, with a stroke of 48 inches. Full power is to be developed with the engines running at 120 revolutions and taking steam at 250 pounds pressure; but the boilers will work at 275 pounds. There will be fifteen boilers in each ship, the total weight of machinery in the Beardmore ship being 1,545 tons and in the Palmer ship 1,560 tons. The vessels are rather shorter than the *King Edward* class, being 410 feet, as compared with 425 feet; but they have a beam of 79.6 feet, as compared with 78 feet, and their depth is 43 feet 1½ inches as against 42 feet 11 inches. The hull is of slightly less weight, and at the same time the cost is less. The weight of the armor of the new ships is barely as great as in the *King Edward* class; but the thickness is more directly proportioned to the vital nature of the area to be protected, and the protection is therefore more effective throughout. There is a slight saving in weight in the machinery, since no cylindrical boilers are being fitted. The whole of the economy in weight from the various items, as well as the increase in displacement, is utilized for the increase in gunpower and ammunition, the result being that greater offensive quality has been attained in this ship with a very slight increase in total displace-

ment, the new vessels being 16,500 tons, while the earlier ships were 16,350 tons.

Black Prince.—LAUNCH OF.—The first-class armored cruiser *Black Prince*, launched on Tuesday, November 8th, 1904, by the Thames Iron Works Shipbuilding and Engineering Company, is of the following dimensions: Length between perpendiculars, 480 feet; extreme beam, 73 feet 6 inches; depth from outer bottom to upper deck, 40 feet 9 inches; draught forward, 26 feet 6 inches; aft, 27 feet 6 inches; displacement, 13,660 tons; indicated horsepower, 23,500; and she is expected to have a speed of over 23 knots. She has a complete armor belt running from stem to stern, the thickness amidships at water line being 6 inches, and tapering at forward end to 4 inches, and 3 inches aft. The citadel, which is rectangular in shape, is protected by 6-inch armor, and carries ten 6-inch breech-loading guns; eight are broadside guns, while the two after ones can fire both athwartship and fore and aft. On the upper deck there are five 9.2-inch guns in barbettes, protected by 6-inch and 3-inch armor, while forward on the forecastle is another 9.2-inch gun, making six in all. The foremost 9.2-inch gun and the aftermost one are situated at the middle line, and an arc of fire of 310 degrees can be obtained. The other four 9.2-inch guns are placed at the sides of the vessel and nearly over the ends of the citadel, and each of these command a fire of 180 degrees.

The shelter decks are well manned with three-pounder quick-firing guns, some twenty-eight in number. There are also two Maxims and two twelve-pounder six-cwt. guns for boats' and field use. The whole weight of armor is about 1,600 tons, exclusive of the protective decks. The battery has a protective deck covering of 1-inch steel, which is continued forward on the main deck. In addition there is the usual sharp cambered protective deck, ¾-inch thick at the water line, running right fore and aft. The 6-inch guns are separated from each other by 2-inch splinter bulkheads. The conning tower is of 10-inch steel, provided with the usual armor tubes for carrying the leads of shafts, pipes, &c., from the shelter deck to within the armor protection. There are three 18-inch torpedo tubes, one on each

side and one at the stern, all under water. One of the new features in the design is the placing of the shellrooms in the ammunition passages close to the ammunition hoists, thus saving much time in getting the shells to the guns. The 6-inch ammunition hoists have electrical motors, while those to the 9.2-inch guns are worked hydraulically. The vessel is ventilated by means of electrically driven fans. The coal, ash and boat hoists are all electrically driven. The vessel will be lighted up with about 1,400 incandescent lamps; she also has an electrical helm indicator, and is well served with electric bells, telephones, &c. The double-bottom is fitted to carry heavy oil, and is fitted with pumps, pipes, filters, &c., to enable the boilers to use oil as fuel if necessary. The coal bunkers can carry, if necessary, about 2,000 tons of coal.

The propelling machinery, which is being constructed at the Company's engineering works at Greenwich and Deptford, is to develop 23,500 indicated horsepower, and to consist of two sets of inverted four-cylinder triple-expansion engines working at a pressure of 205 pounds in the high-pressure slide case. The diameters of the cylinders will be: High-pressure, 43½ inches; intermediate, 69 inches; two low pressure, 77 inches, with a stroke of 42 inches. The engines are balanced on the Yarrow-Schlick-Tweedy system, and arranged to run at a speed of 135 revolutions per minute. There are to be two separate and independent condensers to each set of engines, and two independent twin air pumps arranged to pump from both condensers. The boiler installation will consist of twenty Babcock & Wilcox boilers, and six cylindrical boilers working with closed stokeholds and forced draft. The working pressure of all the boilers is to be 210 pounds per square inch.

Minotaur Class.—Minotaur, Defense, Orion, Shannan.—A number of engineering firms throughout the country have been invited by the Admiralty to send in tenders for the construction of machinery for the three armored cruisers to be built at the dockyards under this year's naval programme. The vessels—which will be built at Devonport, Chatham and Portsmouth—are to be known as the *Minotaur* class. In their design

they mark an important advance on the *Duke of Edinburg* type. They will be 10 feet longer, 490 feet in all, approaching again the 500 feet attained in the *Powerful* and *Drake* classes. This is the maximum reached by warships, as length is regarded always as a necessary evil, so that whenever the 500 feet is approached an effort is put forth to revert to shorter vessels, because they can be more easily maneuvered in harbors or channels of restricted area. The greater length, too, adds to the size of the target. But apart altogether from the injunction laid upon the naval architect to carry increasing loads on lessening draught, necessitating, as it does, increased length of beam, there is the fact that length is a factor conducive to speed. For these reasons our warships, like our high-speed merchant vessels, have been steadily increasing in length. The new ships differ in the strength of their armament. They will carry eight 9.2-inch guns instead of six, as in the *Duke of Edinburg* class; a corresponding reduction being made in the secondary battery. All of the boilers, too, will be of the water-tube type, reverting to Admiralty practice, and conforming with the later view of the Boiler Committee. The engines will be of the four-cylinder, triple-expansion type, and a speed of 22½ knots is anticipated.

Forward.—LAUNCH OF.—On August 27, 1904, the *Forward*, the first of the new scouts, was launched from the Fairfield Shipbuilding Yard, Govan, on the Clyde. Her dimensions are as follows: Length, 384 feet; beam, 39 feet 2 inches; displacement, 2,945 tons; the engines are to develop 16,500 I.H.P., giving a speed of 25 knots, with a bunker capacity of 500 tons. The armament will consist of ten 12-pounder Q.F. guns, eight 3-pounder Q.F. guns, and two 18-inch deck torpedo tubes.

Adventure.—LAUNCH OF.—The scout *Adventure* was launched on September 8, 1904, from the Elswick yard, Newcastle-on-Tyne. Her dimensions are as follows: Length, 374 feet; beam, 38 feet 3 inches; displacement, 2,850 tons, with a draught of 13 feet 3 inches. Her armament will consist of ten 12-pounder and eight 3-pounder Q.F. guns, with torpedo tubes. Her engines, which are to develop 16,000 I.H.P., are to give a speed of 25 knots.

Foresight.—LAUNCH OF.—The scout *Foresight* was launched on October 8, 1904, from the Fairfield Shipbuilding Yard, Govan. The dimensions of the *Foresight* are as follows: Length, 365 feet; beam, 39 feet 2 inches; draught, 14 feet 1 inch, on a displacement of 2,800 tons. The engines are to develop 16,500 I.H.P., to give a speed of 25 knots; the coal capacity will be 150 tons normal, 380 tons possible, giving a radius of action of 3,000 miles at 10 knots. The armament will consist of ten 12-pounder Q.F. guns, eight 3-pounders, and two submerged torpedo tubes.

Patrol.—LAUNCH OF.—The *Patrol*, the second of the two scouts building by Cammell, Laird and Co., was launched on October 12th, 1904, at the shipbuilding works of the company at Birkenhead. The scouts are designed to have a speed of 25 knots on a prolonged trial. The principal dimensions are: Length, 370 feet; beam, 38 feet 9 inches. The propelling machinery consists of two sets of four-cylinder triple-expansion engines of 16,500 horsepower, balanced on the Yarrow, Schlick and Tweedy system, steam being supplied by twelve water-tube boilers of the Laird type, arranged in three watertight compartments. A protective deck is worked throughout the ship, and the engines are protected by 2-inch specially-treated Krupp non-cemented steel made at the company's armor-plate works at Sheffield. The armament consists of ten 12-pounder quick-firing guns, also eight 3-pounder quick-firing guns, and two 18-inch torpedo tubes above water.

The New Destroyers.—The invitations to firms to tender for the construction of the torpedo-boat destroyers to be built under this year's navy programme are being delayed pending the results of certain searching trials of the two latest types of destroyers, the one class of 30-knots speed and the other of 25½-knots. These are not undertaken to determine the question of the strength of the vessels, because no doubt remains regarding the 30-knot boats being equal to all the stresses to which they might be subjected in such services as they might be called upon to perform. The question now being investigated has reference rather to the strength of the machinery and of the section of the ship taking

the strains consequent upon the development of high powers in a seaway. All destroyers are required to develop a high power on very light weight. The increase in displacement in the later 25½-knot boats has necessitated almost as much power per unit of weight as in the lighter faster boats, so that it is not quite certain that the machinery of the later boats is materially stronger than the earlier craft in view of all the circumstances. In other words, it is important to investigate as to whether the great loss in speed carries with it any compensating advantage in the greater durability of the machinery in addition to the better sea-keeping qualities claimed. This latter claim is not fully established, especially in view of the great sacrifice in speed. But it is possible that both benefits may weigh the balance in favor of a boat slightly heavier than the 30-knot craft.—"Practical Engineer."

Boyne.—LAUNCH OF.—The torpedo-boat destroyer *Boyne*, of 550 tons displacement, 7,000 horsepower, 25.5 knots, was launched September 12th, from the Hebburn-on-Tyne works of Hawthorn, Leslie & Company. Four boilers of the Yarrow modified type are to be installed in three compartments.

This vessel is one of the same class as the *Doon* and *Kale*, next mentioned.

Doon and Kale.—LAUNCH OF.—The two new destroyers *Doon* and *Kale*, launched from the Hebburn shipyards of Hawthorn, Leslie & Co., are of the *Derwent*, or improved destroyer type, 220 feet long, with machinery working at 350 revolutions and developing 7,000 I.H.P., and make five of this type which this yard has turned out. The engines for both vessels have been constructed at the St. Peter's Works of the firm, and will be immediately fitted on board.

Liffey.—LAUNCH OF.—This torpedo-boat destroyer, the first of the second series of three each of 550 tons, 7,000 horsepower, and 25.5 knots to be launched from the works of Laird & Cammell, Birkenhead, was launched on September 25th.

Kennet, Jed.—TRIALS OF.—The torpedo-boat destroyer *Kennet* was given her official trials on August 27th, in which a mean speed of 25.894 knots was maintained on six runs over the

measured mile. During a full-power trial of three hours the mean speed per hour was 25.666 knots.

The *Jed*, a sister vessel of the *Kennet*, commenced her trials on September 6th.

These vessels were mentioned on page 1008 of the last issue of the JOURNAL.

Decoy.—LOSS OF.—On the night of August 13th, a collision occurred between the *Arun* and *Decoy*, which proved fatal to the latter. The night was very dark, and it was blowing fairly hard. The *Arun*, *Sturgeon* and *Decoy* were proceeding in line ahead, without lights, when the *Arun*, without signal, altered course some sixteen points, unperceived by the *Decoy*, which vessel was struck amidships. As the *Decoy* kept afloat for about half an hour, time was thus fortunately given for the rescue of all the crew.

Sparrowhawk.—LOSS OF.—The destroyer *Sparrowhawk* on the China station struck, on the night of the 17th of June, a rock, unmarked on the chart, northeast of Chesney Island, one of the Parker group. The chart showed eight fathoms of water. After hard work she was re-floated and brought alongside the flagship *Glory;* all her guns, torpedoes, ammunition and loose gear were saved, but shortly after being brought alongside the flagship she sank in eight fathoms. She had struck a pinnacle rock, which pierced her hull just abaft the third funnel, and it is supposed the engineroom bulkhead broke after she had been towed off, which caused her to part between the second and third funnels.

Chamois.—LOSS OF.—During a series of forced-draft runs of this vessel one of the propellers was smashed—perhaps by a floating log being drawn into it—in such a manner that the hull was pierced.

With the breaking of the propeller blades the port engine was wrecked before it could be stopped, which perhaps further weakened the hull.

Water entered with such force that the after watertight bulkheads were collapsed, and the machinery compartments were flooded. When it was seen that the pumps could not be used,

the vessel was abandoned, and sank within a very few moments, the crew being taken on board the *Exe* and *Kangaroo*.

Spiteful.—OIL FUEL TRIALS.—The destroyer *Spiteful* was commissioned at Portsmouth recently in order that a long series of oil fuel trials may be carried out. All the *Spiteful's* furnaces have been adapted for the consumption of this kind of fuel, and the vessel is, in fact, the first British warship to rely on oil fuel. No coal whatever will be carried for generating steam. Experiments are still being carried out on the destroyer *Surly*, as well as on the old battleship *Sultan*, and at the experimental works at Haslar. It is evident that the Admiralty are going in more extensively for oil fuel. Three old "flat-iron" gunboats have had all their machinery lifted out and have been converted into floating oil tanks for supplying fuel to warships. Orders have now been given that when the battleships *Mars* and *Hannibal* are again in dockyard hands more of their boilers are to be adapted for the consumption of oil fuel.

Comparative trials between destroyers are taking place daily in the Channel. As far as can be ascertained the experiments up to the present time have been in favor of oil fuel, its general handiness and utility having proved superior to coal. A full pressure of steam can be raised with oil in less than half the time required with coal. Other advantages are its greater cleanliness, the furnaces not becoming choked as they do with coal, and the smaller number of men required in the stokehold. The relative cost of the two fuels appears about equal. The only possible danger likely to occur would be the igniting of the oil, as happened lately on board the *Spiteful*; but this would not take place in a vessel specially built for oil fuel, the *Spiteful* having been merely adapted for the purpose.

New Submarines.—The first of a new type of submarine for the British Navy, to be known as the *B* class, has just been launched at Barrow from Vickers, Sons and Maxim's Naval Construction Works. Twelve of the *A* class have already been built, but the new type is larger, and embodies many improvements, particularly in the internal construction. The new submarine is 150 feet long and 63 feet girth.

FRANCE.

Edgard Quinet.—It has now been decided that this new armored cruiser, which appeared in the estimates for this year as *C 16*, is to be laid down at Brest. She is to be of an improved *Ernest Renan* type, and will be the largest cruiser as yet built for the French Navy. Her dimensions will be as follows: Length, 528 feet; beam, 69 feet 4 inches; displacement, 14,300 tons, with a draught of water of 26 feet 6 inches. Protection will be afforded by a complete water-line belt of steel, 6.7 inches thick amidships, tapering to 3.6 inches at the extremities, with a depth of 7 feet 6 inches; above this belt is another, reaching to main deck, but carried up to the upper deck at the bow, 5 inches thick, tapering to 2.2 inches at the bow and stern. The armor on the main turrets will be 8 inches, with 5-inch ammunition hoists; on the turrets for the secondary armament 5.5 inches, and on the casemates 4.7 inches. A cofferdam filled with cellulose will run round the ship to a height of 16 feet above the water line, and there will be an after transverse bulkhead 6 inches thick. There will be two armored decks, the lower 2.4-inch, and the upper 1.3-inch. The armament will consist of two 24-cm. (9.4-inch) 50-caliber guns (1902 Model) in turrets, one forward and one aft; sixteen 164.7-mm. (6.4-inch), Q.F. 50-caliber guns, twelve in pairs in the upper-deck turrets (of which there will be three on each broadside), and four in the main-deck casemates; eight 6-pounder Q.F., and sixteen 3-pounder Q.F. guns, with 5 torpedo tubes, two submerged. The ship will have three sets of main engines, which are to develop 40,000 I.H.P., and give a speed of 24 knots. The ordinary coal stowage will be 1,500 tons, but the ship will be able to carry, when necessary, 2,400 tons, which will give a radius of action of 7,000 and 12,000 miles at 10 knots speed respectively, and 1,100 and 1,700 miles at full speed. It is not yet known with what boilers she will be fitted.

The following comparative table of recently constructed cruisers may be of interest:

Name and Nationality.	Length.	Displacement	I.H.P.	Speed.	Armament.
	ft. ins.	*tons.*		*knots.*	
Drake (English)	529-6	14,100	30,000	23	Two 9.2-inch; sixteen 6-inch; fourteen 12- and four 3-pounders.
Black Prince (English)	480	13,500	23,500	22.5	Six 9.2-inch; ten 6-inch and twenty 3-pounders.
California (United States)	502	13,400	23,000	22	Four 8-inch; fourteen 6-inch; eighteen 14- and twelve 3-pounders.
Tennessee (United States)	504-6	16,000	25,000	22	Four 10-inch; sixteen 6-inch; twenty-two 14- and twelve 3-pounders.
Edgard-Quinet (French)	528	14,300	40,000	24	Two 9.4-inch; sixteen 6.4-inch; eight 6- and sixteen 3-pounders.
Leon-Gambetta (French)	482	12,550	27,500	22	Four 7.6-inch; sixteen 6.4-inch; twenty-two 3-pounders.

—J. R. U. S. I.

Dupetit Thouars.—The armored cruiser *Dupetit Thouars* is one of the eight ships of the *Gueydon* and *Montcalm* class. The characteristics are: Length, 460 feet; beam, 64 feet; draught, 24½ feet; displacement, 9,517 tons. This cruiser has three independent engines, actuating each its own screw, of a combined horsepower of 19,600. The armament consists of two 7½-inch guns, eight 6½-inch guns, four 4-inch guns, sixteen 47-mm. guns, six 37-mm. guns, and four torpedo tubes.

Léon Gambetta.—TRIALS OF.—The first-class armored cruiser *Léon Gambetta* developed a speed of 20 knots with an average horsepower of 16,050 during her twelve-hours' normal-conditions trial on August 26.

During a full-power run of two hours and thirty-five minutes on the 27th, 25,000 horsepower was developed, giving a mean speed of 22.2 knots, .2 greater than the contract requirement.

Torpedo Boat No. 283.—The trials of this torpedo boat have been carried out with satisfactory results, giving a reported mean speed of 26.16 knots, which is .16 greater than the contract requirement.

Turbines for Experiment.—Three torpedo boats are now being fitted with turbine engines on different systems for experimental purposes: *No. 243* with the Renard turbine, *No. 293* with the Parsons, and *No. 294* with the Breguet.

Submarines.—Three submarine vessels of an entirely new type have been laid down simultaneously at Cherbourg. They are to be named the *Emeraude*, the *Opale* and the *Rubis*. As is the case

with the boats of the *Norval* class, they will have double hulls. The length of each will be 148 feet, the beam 13 feet 1½ inches, and the displacement 600 tons. A speed at the surface of 12 knots is to be obtained by a machinery of 600 horsepower, driven by a benzine or other internal-combustion engine. When submerged the machinery will be worked by an electric motor, driven by accumulators. It is reported that each boat will have twin screws and six torpedo tubes.

GERMANY.

New Battleships.—The new battleships of the *N* class are to have the same dimensions, displacement, engines and speed as the *Braunschweig* class, namely: Length, 398 feet 8 inches, 430 feet over all; beam, 72 feet 10 inches; draught, 25 feet 3 inches; displacement, 13,200 tons; engines, 16,000 indicated horsepower, and speed, 18 knots; but there will be a considerable difference in the boilers, armor and armament, and in the distribution of the latter. The *Braunschweig* is fitted with six cylindrical boilers and eight Thornycroft-Schulz water-tube boilers; the battleships *N* will have no cylindrical boilers and twelve Thornycroft-Schulz boilers. The armor belt of the new vessels will have a thickness of 9½ inches amidships, tapering to 5.9 inches forward and 3.9 inches aft. The armament will comprise four 11-inch, ten 6.7-inch in battery and four in single casemates, twenty-two 3.46-inch and four 1.45, besides mitrailleuses and landing guns. The *N*, like the *Braunschweig*, will have six torpedo tubes, five of which will be submerged. Now that the question of naval boilers has once more been brought prominently before us by the recently-issued report of the British Boiler Committee, it is of interest to note from the above that the German naval authorities have discarded the cylindrical boiler in favor of the Thornycroft-Schulz water-tube boiler. Hitherto it has been customary in German battleships and large armored cruisers to fit a combination of this type of water-tube boiler with cylindrical boilers. The proportion of the former has steadily increased from 40 per cent. of the total power to 100 per cent. in the battleships about to be laid down.

ITALY.

Regina Margherita.—DESCRIPTION AND TRIALS.—The battleship *Regina Margherita* completed her official contract steam trials, and attained most satisfactory results. She is of 13,430 tons displacement, 427 feet long, 78 feet beam and 27 feet draught, built at the Royal dockyard of Spezia. The machinery was constructed by the firm of Gio. Ansaldo, Armstrong & Co., of Genoa, at their engineering works at Sampierdarena.

The protective armor consists of a H.S. belt extending to within a short distance of the stern, and having a height of 6 feet above the water line, and a depth of 3 feet 6 inches below. Amidships the belt armor is 6 inches thick, and diminishes towards the two ends to 2 inches thick. The ends of the citidal are enclosed by transverse bulkheads 10 inches thick, and the armor deck varies in thickness from 1½ inches to 3 inches. The heavy gun positions are protected by H. S. armor 8 inches thick, and the secondary gun positions by H. S. armor 6 inches thick.

The armament consists of four 12-inch guns, two of which are mounted in a turret forward and two aft, these turrets being protected by 6-inch H. S. armor. There are four quick-firing guns in turrets at angles of the citidal on the upper deck, and in addition to these there are twelve quick-firing 6-inch guns in the battery, as well as sixteen 3-inch, eight 1.8-inch, and six machine guns on the upper deck. There are six submerged torpedo tubes. The ahead and astern fire of the vessel comprises two 12-inch guns, two 8-inch guns, and two 6-inch guns; while the broadside fire includes four 12-inch, two 8-inch, and six 6-inch guns.

The ship has a coal capacity of from 1,000 to 2,000 tons, and carries 35 officers and 749 men.

The machinery consists of two main engines, fitted with all the necessary auxiliary engines, steam being supplied by twenty-eight Niclausse water-tube boilers. Each set of engines is placed in a separate engine room, divided by a longitudinal watertight bulkhead, and the engine rooms are in all respects exactly similar and entirely independent of each other.

The boilers are placed in six separate rooms forward of the engine rooms, three on port side, and three on starboard side,

divided by a longitudinal watertight bulkhead. The working pressure of the boilers is 300 pounds, being reduced to 250 pounds at the engine rooms.

The main engines are of the four-cylinder triple-expansion type, the diameter of the cylinders being 37 inches for the high-pressure, 60¼ inches for the intermediate, and 69¼ inches for the two low-pressure; the stroke is 47¼ inches.

The engines are balanced on the Schlick system, the two low-pressure cylinders being in the center, and the high and intermediate cylinders at the ends, which balancing proved most effective. Stephenson link motion is adopted for the valves, which are of the piston type on the high and intermediate-pressure cylinders, and of the double-ported flat design on the low-pressure cylinders. The reversing gear is of the all-round type, fitted with a double-cylinder engine. The screws turn inward, and the starting platforms are in the center of the ship.

The crank shafts are hollow, and each consists of four interchangeable pieces, $18\frac{5}{16}$ inches in external diameter, both at journals and at the crank pins. Each crank pin is 20⅞ inches long, and each engine has eight main bearings, with a collective length of 13 feet 8 inches. The thrust shafts have an external diameter of $18\frac{5}{16}$ inches, and the thrust blocks are of the horseshoe type, with a collective surface of 15 square feet. The propeller shafts are $18\frac{5}{16}$ inches in external diameter. There are two main condensers, total cooling surface 20,500 square feet. The water is supplied by four circulating pumps, each capable of discharging 1,000 tons of water from the bilge per hour. The main air-pumps are four in number, worked by the intermediate and aft low-pressure cylinders; they are each 26 inches in diameter and 20½ inches in stroke; there are also two auxiliary air pumps for keeping the vacuum in the main condensers when the main engines are at rest. The propellers are three-bladed, and have a diameter of 18 feet 8½ inches, and pitch, 19 feet 8¾ inches. The bosses are of gun metal, and the blades are of manganese-bronze.

The distilling machinery for the purpose of furnishing fresh water for the boilers consists of four sets of Ansaldo evaporators

with pumps complete, capable of furnishing collectively 80 tons of fresh water per day.

The boilers are of the Niclausse water-tube type, twenty-eight in number; each has 15 headers with 18 tubes, and there are therefore, collectively, 420 headers with 7,560 tubes. The tubes have an outside diameter of 3¼ inches, and a length of 7 feet 10⅜ inches; the headers are of malleable cast iron, and the tubes are of steel solid drawn. Each boiler has one furnace and three fire doors. The aggregate heating surface of the twenty-eight boilers is 50,310 square feet, and the total grate area is 1,555 square feet. There are three funnels 92 feet in height from the grate bars.

The boiler rooms are arranged for assisted draft in closed stokeholds, but non-airtight; the maximum air pressure admitted is ⅜ inch. The air pressure is furnished by twelve electric fans. Twelve electric ash-hoisting engines, with electric brake and automatic stop gear, are also fitted.

There are six main feed pumps and six auxiliary feed pumps, all of the same sizes, and of duplex type, fitted in the boiler rooms.

The machinery is fitted with all the latest apparatus usual in vessels of this class; we enumerate here the Molinari's electric counters, and the Perroni's automatic signaller for regulating the rate of firing, which were found very useful. The total weight of machinery complete, including water in the boilers, is 1,550 tons.

The official trials took place in the Gulf of Genoa, in last July, and it may be said at the outset that they have proved eminently satisfactory. The contract fixed a 6-hours' steam trial at 16,000 indicated horsepower with natural draft and coal consumption not to exceed 1.87 pounds per indicated horsepower hour; and a 1½-hours' steam trial at full power of 19,000 indicated horsepower with assisted draft at an air pressure not greater than ⅜ inch.

The first trial, at natural draft, took place on July 16, 1904; the mean power developed during the six-hours' run was 17,782 indicated horsepower; the coal consumption was 1.84 pounds per indicated horsepower hour.

The second trial, with assisted draft, took place on July 21, 1904, the mean power developed during the one-and-a-half hour's run was 20,664 indicated horsepower, with an air pressure of $\frac{3}{16}$ inch and a coal consumption of 1.98 pounds per indicated horsepower hour.

In both the trials all the main and auxiliary engines worked very satisfactory, and the boilers produced the steam supply without difficulty.

SIX-HOURS' COAL-CONSUMPTION TRIAL AT 16,000 I.H.P., NATURAL DRAFT, JULY 16, 1904:

		Forward.		*Aft.*
Draught of water, feet		27		27
Steam pressure in boilers, pounds			261	
		Starboard.		*Port.*
Vacuum, inches		26.5		26.3
Revolutions per minute		115.4		114.6
Steam pressure at high-pressure receivers, pounds		235		230
Indicated horsepower	High	2,800		2,750
	Intermediate	3,008		2,980
	Low forward	1,550		1,537
	Low aft	1,609		1,548
Mean total indicated horsepower		8,967		8,815
Mean collective indicated horsepower			17,782	
Speed of vessel, knots			19.3	
Coal consumption per I.H.P. per hour, pounds			1.84	

ONE AND ONE-HALF HOUR'S FULL-POWER TRIAL, JULY 21, 1904:

		Forward.		*Aft.*
Draught of water, feet		27		27
Steam pressure in boilers, pounds			279	
		Starboard.		*Port.*
Vacuum, inches		26.1		26.3
Revolutions per minute		120.8		121.2
Steam pressure at high-pressure receivers, pounds		242		240
Indicated horsepower	High	3,108		3,218
	Intermediate	3,375		3,371
	Low forward	1,894		1,905
	Low aft	1,889		1,908
Mean total indicated horsepower		10,262		10,402
Mean collective indicated horsepower			20,664	
Mean air-pressure in stokeholds, inch			$\frac{3}{16}$	
Speed of vessel, knots			20.2	
Coal consumption per I.H.P. per hour, pounds			1.98	

Vittorio Emanuele.—LAUNCH OF.—The King of Italy launched at Castellamare, near Naples, on October 12, the battleship *Vittorio Emanuele III*, sister vessel of the *Regina Elena*, recently launched at Livorno. She has twenty-eight Belleville boilers; her length is 435 feet and her breadth 73 feet 6 inches; she carries fourteen large and twenty-eight smaller guns; her engines are of 19,000 horsepower. Two other vessels of the same type, to be christened *Roma* and *Napoli* respectively, are now under construction. [See JOURNAL, May, 1904, p. 705.]

RUSSIA.

Emperor Alexander III.—The first-class battleship *Emperor Alexander III* is one of a class of five, the others being the *Borodino*, the *Orel*, the *Slava* and the *Kniaz-Suvaroff*.

The dimensions of these ships are as follows: Length, 397 feet; beam, 76 feet; draught, 26 feet; displacement, 13,600 tons; speed, 18 knots.

The armament consists of four 12-inch guns, twelve 6-inch guns, twenty 3-inch guns, twenty 47-mm. guns and eight 37-mm. guns and four torpedo tubes.

Schemtschug.—TRIALS OF.—This protected cruiser has successfully completed her trials, the speed attained being reported as 23 knots.

MERCHANT SHIPS.

Victorian.—New Turbine Steamer.—There was successfully launched on August 25th, by Workman, Clark & Co., Belfast, the steamer *Victorian* of 12,000 tons, the first of two turbine-driven ships ordered by the Allan Line. The second, which is building on the Clyde, is to be named the *Virginian*, and will be a sister ship to the *Victorian* as regards dimensions, capacity and power. The pair will form a notable reinforcement to the fine fleet of the Allan Line, which already numbers twenty-eight steamers, and comprises several of 10,000 tons, each engaged in the mail, passenger and general service between the United Kingdom and Canada. The *Victorian*, which is expected to be ready for sea before the end of the year, is the pioneer turbine vessel for the Atlantic or any other ocean service, and is one of the handsomest craft ever built at Belfast. Messrs. Allan have previously led the way in many prominent advancements in connection with Atlantic craft, and therefore they are the more to be congratulated as the pioneers in the adoption for ocean travel of a means of propulsion which it is believed has such a great future.

The length of the *Victorian* is 540 feet; her breadth, 60 feet; her depth, 40 feet 6 inches; and she is divided by bulkheads into eleven compartments; whilst with the subdivisions of her double bottom she has twenty watertight spaces. She is built to the highest class of the British Corporation registry of shipping, and her hull has been specially strengthened above the requirements of the corporation in order to make her doubly secure against the heavy weather of the North Atlantic. When ready, the *Victorian* will take her place in the Liverpool and Canadian service. She is largely an experimental ship, and by her trial trip the problem will practically be solved of whether turbines will successfully propel ocean steamers. Whatever may

be the result, with the Allan Line will rest the honor of leading the way with an important economical venture. Originally the *Victorian*, the keel of which was laid ten months ago, was designed to be driven by reciprocating engines, but after some progress had been made with the hull, and while other companies were hesitating to plunge into a practical experiment which might involve heavy loss, the owners boldly assumed the responsibility of giving the lead, and decided that the new vessel should have turbines. Workman, Clark & Co. made the necessary alterations in her structural design, and at the same time undertook what was a far more difficult and delicate task, the construction of the great turbines—the largest ever made—which are to drive her. This was by arrangement with Parsons & Co., for it was the Parsons turbine that was decided upon.

A high-pressure and two low-pressure turbines will drive the three propellers of the ship, which, by the way, strike one as being unusually small to drive a vessel possessing a cargo capacity of more than 8,000 tons, besides accommodation and equipment for upwards of 1,300 passengers. These propellers, however, revolve at very high speed—from 270 to 300 revolutions per minute. The central one, arranged as in a single screw-vessel, is worked by the high-pressure turbine, the others, which are arranged as in a twin-screw ship, by the low-pressure turbines. The two latter have each a reversing arrangement which enables them to be driven full speed astern, either together or independently. Thus the ship will be as easily and effectively maneuvered as regards turning or backing as an ordinary twin-screw. This disposes of the objection which has sometimes been urged against turbines, that they are defective with regard to reversing motion.—"Marine Review."

Victorian.—UNSATISFACTORY TRIALS.—A special from Glasgow states that the trials of the new turbine-propelled steamship *Victorian*, which is the largest vessel yet built to demonstrate this new type of machinery, which was launched at Belfast, August 25, have been so disappointing as to raise serious doubts among the Clyde shipbuilders as to the value of turbines in the case of large ships. All the efforts made to get the *Victorian* near con-

tract speed were futile, and it is understood that the construction of the turbine engines intended for the new Cunard Line steamships has been suspended pending developments. A sister ship of the *Victorian* will be launched next month. The two vessels were built on the understanding that the new contract for the fast Canadian mail service would be given to the Allan Line.

Great surprise has been manifested among marine engineers in this country over the failure of the *Victorian* to make the required speed.

America and Kaiserin Auguste Victoria.—The great size and carrying capacity of the new steamships of the Hamburg-American Line can be best understood by reference to the following statistics:

America.—Length over all, 700 feet; breadth, 74 feet; depth, 53 feet; gross tonnage, 23,500 tons; displacement about 35,000 tons; cargo capacity, 15,000 tons.

Kaiserin Auguste Victoria.—Length over all, 705 feet; breadth, 77 feet; depth, 53.9 feet; gross tonnage, 25,000 tons; displacement, about 40,000 tons; cargo capacity, 16,000 tons.

The *America* will be ready for service in August, 1905, and the *Kaiserin Auguste Victoria* in the spring of 1906. The former ship is being built by Harland & Wolff, Belfast, Ireland, and the latter by the Vulcan Shipbuilding Works, Stettin, Germany.

The passenger capacity of these ships will be about 3,589 each, comprising 600 in first class, 300 in second class, 250 in third class, and 2,139 in the steerage.

The speed of the *America* and *Kaiserin Auguste Victoria* will be moderate—17 knots an hour. This speed will enable these steamers to reach Plymouth and Cherbourg in about seven and a half days and Hamburg in nine days. The dimensions of these steamers, their cargoes of freight, and their bilge keels will make them steady in the roughest seas. Vibration will be avoided by installing balanced engines of the most modern type.

Manxman.—Trials of.—The new turbine-driven steamer *Manxman*, built by Vickers Sons & Maxim, at Barrow-in-Furness, for the Midland Railway Company, has completed a series of official trials. The performance establishes a record for turbine-

driven merchant vessels. Hitherto the steam pressure adopted in all turbine vessels has been 150 pounds; but in this vessel it was decided to generate steam at 200 pounds, and to proportion the Parsons turbines, with which the vessel is fitted, accordingly. The careful measurement of the water consumption, and, therefore, of the amount of steam used, shows that the increased steam pressure gives higher economy. In respect also of speed, the vessel ranks first, the mean speed attained, with full power, being 23.004 knots; while, on a continuous six-hours' run in the estuary of the Clyde, an average of 22¾ knots was easily maintained. At this speed the revolutions of the center shaft, which is driven by a high-pressure turbine, were 530, while the side shafts, which are operated by low-pressure turbines, made 610 revolutions per minute. The vacuum was as high as 29 inches. A highly satisfactory test was also made of the time taken to bring the ship to a dead stop when running at full speed. The Midland Company have built three other steamers, two with reciprocating engines and one with turbine machinery. This latter attained a speed of 22.27 knots; while the best recorded for the reciprocating-engined ships was 21.9 knots. In the course of the trials several runs were made over the measured mile at various speeds, and in all cases the results were eminently satisfactory. A maximum speed of over 23 knots was reached on three different tests during the course of the two days' trials. The *Manxman* is for a passenger service to the Isle of Man, although she may also be used on the Belfast route.

For previous mention and description of this vessel, see page 1023, Vol. XVI, No. 3, August, 1904.

Donegal.—TRIAL OF.—On August 11th this twin-screw steamer, built by Caird & Co., Greenock, to the order of the Midland Railway Co., proceeded to sea for her trial trip. Her dimensions are 330 × 42 × 25.9 feet. She is one of the four steamers which are to run on the new route which the Midland Co. are about to open up between Heysham harbor and Ireland. She attained a mean speed of 20½ knots.

YACHTS.

Tarantula.—It will be of interest to note that the owner has placed the contract for new boilers for this vessel, a course which was predicted in the report by the Board which visited the *Tarantula* under orders from the Bureau of Steam Engineering. (See page 1110.) The two boilers to be removed are of the Yarrow small-tube type—total H.S., 3,680 square feet; total G.S., 65 square feet; weight, with water and fittings, about 22 tons. There will be installed two Mosher boilers of the latest design, having a total H.S. of 5,620 square feet; total G.S. of 120 square feet; and weighing 21.9 tons. In spite of the greatly increased heating and grate surface of the new boilers, they accommodate themselves very well to the space occupied by the old boilers, and weigh even less than the Yarrow boilers of smaller capacity.

OBITUARY.

It is with the most profound regret that the Council announces the loss sustained by the Society in the death of three of its members since the last issue of the JOURNAL.

Chief Engineer J. L. D. Borthwick, U. S. N. (Retired), died October 22, 1904, at Florence, Italy.

James T. Boyd, Esq., died November 3, 1904, at Boston, Mass.

Lieutenant Morris H. Brown, U. S. N., died December 6, 1904, at Washington, D. C.

NOTES OF THE SOCIETY.

NOMINATIONS FOR OFFICERS FOR 1906.

A regular meeting of the Society was held at the Navy Department, October 4th, at which nominations were made for Officers of the Society for the coming year.

The following nominations were made:

For President.

Commander A. F. DIXON, U. S. N.
Lieutenant Commander B. C. BRYAN, U. S. N.
Rear Admiral C. R. ROELKER, U. S. N., Retired.
Commander W. B. BAYLEY, U. S. N.
Commander A. B. CANAGA, U. S. N.

For Secretary-Treasurer.

Lieutenant Commander W. W. WHITE, U. S. N.
Lieutenant C. K. MALLORY, U. S. N., Retired.

For Members of Council.

(Three to be selected.)

Commander J. K. BARTON, U. S. N.
Chief Engineer FREDERICK G. MCKEAN, U. S. N., Retired.
Commander W. M. PARKS, U. S. N.
Lieutenant H. V. BUTLER, U. S. N.
Commander I. S. K. REEVES, U. S. N.
Rear Admiral W. L. CAPPS, U. S. N.
Chief Engineer C. A. MCALLISTER, U. S. R. C. S.
Captain GEORGE W. BAIRD, U. S. N.

Owing to his many official duties, which would prevent him from devoting the necessary time to this work if elected, Rear Admiral W. L. Capps, U. S. N., requested that his name be withdrawn from nomination.

A similar request for withdrawal from nomination was received from Chief Engineer F. G. McKean, U. S. N. (Retired).

The vote will be secured by the usual voting slips, which have been forwarded to all members, and will be counted at the Annual Meeting to be held in the Bureau of Steam Engineering Navy Department, at 2 P. M., Saturday, December 24, 1904.

BOOKS RECEIVED.

NAVAL ENGINES AND MACHINERY.—By Commander JOHN K. BARTON, U. S. Navy, Head of Department of Engineering and Naval Construction, U. S. Naval Academy. Published by the UNITED STATES NAVAL INSTITUTE, Annapolis, Maryland. 8vo, 570 pages, full cloth. Price $6.50. Postage 38 cents. Illustrated by 260 text plates and by 35 separately bound plates 8×10.

This work is published as a text-book for the instruction of Midshipmen at the Naval Academy and for reference use by officers in their preparation for examinations. It is none the less interesting to other readers, however, and will be found particularly useful to all who desire a concise, practical and comparatively brief treatise on marine machinery.

The following is the summary of subjects covered by the various chapters in sequence:

I. Work and Efficiency.—II. The Action of the Steam.—III. Description and Nomenclature of Naval Engines.—IV. The Slide Valve.—V. Valve Gear and Reversing Arrangements.—VI. The Multiple Expansion Engine.—VII. Cylinders, Details, Attachments.—VIII. Crosshead, Connecting Rod, Crank Shaft.—IX. Condenser and Its Fittings.—X. The Indicator.—XI. Curves of Crank Effort.—XII. Drainage, Pumping and Fire System.—XIII. Propulsion and Screw Propellers.—XIV. Auxiliary Machinery.—XV. Steam Turbines.—XVI. Engine Balancing.—XVII. Operation and Management.—XVIII. Port Service, Examinations, Adjustments and Repairs.—XIX. The Organization of the Engineer Division, Assignment of Men, Station Bills, Coaling Details, etc.

Appendix.—Regulations for the Care and Preservation of Machinery—Spare Parts Carried on Board Ship—Workshop Machinery—Tools, etc.—Steam Tables—Navy Specifications for Stores and Material—Inspection of Material, Steel and Iron,

Copper, Brass and Bronze—Comparison of the Different Methods of Working Evaporators—Examination Questions in Engineering for Line Officers for Promotion.

While each of the chapters possesses excellence of detail, there are several chapters in which the arrangement and clearness of the subject-matter will appeal to those to whom want of time forbids extended research.

Among the subjects of timely interest will be found the chapters on The Indicator (X), *Propulsion and Screw Propellers* (XIII), *The Steam Turbine* (XV), *Engine Balancing* (XVI), and the sections of the *Appendix* relating to specifications, tests and requirements for supplies and materials.

WAR SHIPS.—A Text-book on the Construction, Protection, Stability, Turning, etc., of War Vessels, by EDWARD L. ATTWOOD, M. Inst. N. A. With numerous diagrams. New York: LONGMANS, GREEN & Co. Price, $3 net; $3.20 by mail.

The author, Mr. Attwood, has already established a reputation for accuracy of details and broad knowledge of conditions in his Text-Book of Theoretical Naval Architecture, so that this new work will be gladly received by students in that particular branch of naval architecture which deals with war ships.

To naval officers, moreover, this work will be of especial interest, giving, as it does, much valuable information on those details to which reference is made daily in the course of their various duties, inspections and surveys.

The appended questions will be found of service to those officers, students, or others who are preparing for examinations, and who wish to refresh their memories on special details.

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